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Metropolitan Washington Council of Governments
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AN EVALUATION OF THE COSTS OF STORMWATER MANAGEMENT POND CONSTRUCTION AND MAINTENANCE

Prepared for

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ABSTRACT

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AGENCY: The Metropolitan Washington Council of Governments (COG) is the regional organization of the Washington, D.C. area's major local governments and their governing officials. COG works towards solutions to such regional problems as energy shortages, traffic congestion, inadequate housing, air and water pollution. The Washington Metropolitan Water Resources Planning Board serves as the areawide wastewater management agency for the Washington area. The Board is involved with regional policy issues related to provision of adequate wastewater treatment, sludge disposal, nonpoint source pollution, and municipal water supplies.

REPORT ABSTRACT: Presents planning level approach to estimating or projecting costs of stormwater management pond construction and maintenance. Describes survey methods and statistical analysis used to determine correlation between pond volume and construction costs. Itemizes maintenance tasks reported by stormwater management/public works agencies in Washington, D.C. area and other agencies contacted around U.S. Presents cost projections in terms of costs to homeowner and commercial property. Report prepared as part of the Washington, D.C. urban runoff project, EPA Nationwide Urban Runoff Program (NURP). A separate report summarizing findings and conclusions for the entire Washington NURP project is available through the Metropolitan Washington Information Center (see below).

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PREFACE

This report on the costs of stormwater management pond construction and maintenance was prepared by the Metropolitan Washington Council of Governments (COG) as part of the EPA Nationwide Urban Runoff Demonstration Program (NURP), Metropolitan Washington project. The EPA NURP effort is directed at obtaining new information on the pollution impacts of urban stormwater runoff and the cost-effectiveness of different control devices, or "Best Management Practices" (BMPs), including retention/detention ponds or basins.

COG gratefully acknowledges the assistance provided by the organizations mentioned in this report and the National Association of Home Builders, the Northern Virginia Builders Association, and the Suburban Maryland Home Builders Association for their technical assistance in developing the unit cost survey utilized in this report, as well as for providing various pond site and cost information.

The Washington NURP project is managed by the Council of Governments in association with the Northern Virginia Planning District Commission (NVPDC) and the Virginia Polytechnic Institute and State University.

A final report summarizing study findings and conclusions for the entire Washington NURP project is available separately from the Council of Governments.

EXECUTIVE SUMMARY

On-site detention and retention basins are increasingly being used in the Washington, D.C. metropolitan area as stormwater management devices to reduce the impacts of post-development runoff as well as to serve as "Best Management Practices" or BMPs designed to control pollutants washed off urban land surfaces. This report attempts to provide new guidance to public and private sector engineers and planners interested in projecting the costs of stormwater management (SWM) pond construction and maintenance over a specified planning period. Construction cost projections were derived from an extensive unit cost survey of local SWM agencies and private firms involved in design and construction of stormwater management projects throughout the region. Information on required aspects of pond maintenance programs and their associated costs were developed from current SWM literature and the reported field experience of a cross-section of local SWM agencies and other public works agencies around the country. The resulting analysis is intended to build upon more locally oriented cost studies conducted to date and to provide additional detail on the nature and scope of public and private sector responsibilities associated with long-term pond maintenance. Report conclusions include:

1. Pond construction costs, based on unit cost estimates and statistical analysis of 31 Washington Area dry and wet ponds, ranging in size from 2,700 to 740,000 cubic feet of storage, revealed a nonlinear relationship between volume of storage and construction costs. This cost relationship compares favorably with earlier projections developed by the Soil Conservation Service in 1977 for on-site pond construction in Montgomery County, but projected costs are somewhat lower, on the order of 10 percent.

2. Construction costs per unit of storage were generally found to decrease with increased pond size, suggesting economies achieved by constructing larger ponds which serve a larger portion of the drainage area as opposed to construction of several smaller ponds.

Total pond construction costs, translated on a cost per dwelling unit basis, indicated that:

- For 20-acre developments, dry pond construction costs amounted to about $230 per dwelling unit for a medium density single family development (4 D.U. per acre) and about $110 per dwelling unit at a townhouse/ garden apartment development (10 D.U. per acre).

- For ponds serving 100 acre developments, unit costs declined such that dry pond construction amounted to about $110/D.U. at a medium density single family development, and about $50/D.U. at a townhouse/garden apartment site.

3. Wet pond construction (assuming a permanent pool storage equal to one-half inch of runoff over the drainage area) appears to cost 26 to 46 percent more than single purpose dry pond construction, primarily due to the extra pond volume required to achieve the permanent pool area in addition to the peak shaving storage requirement. Several factors may weigh in favor of wet pond construction despite these additional costs, including the exceptional pollutant removal characteristics of wet ponds, and instances where site topography can accomodate the additional pond volume without substantial additional excavation.

4. Preliminary evaluation of 12 off-site ponds, ranging in size from 63,000 to 3,000,000 cu ft of storage, also show a trend towards decreased unit storage costs with an increase in pond size. However, off-site construction costs appear to rise more sharply with volume increases than appears to be the case with the on-site ponds analyzed in this report. This difference may be due to the more complex structural and siting requirements associated with larger, centralized facilities.

5. Information assembled on stormwater management pond operation and maintenance practices experienced in the Washington region and elsewhere in the U.S. appears to support the practice of utilizing 5 percent of construction costs as a realistic and fairly conservative "rule of thumb" estimate for projecting O&M costs for these structures. Maintenance practices identified include a number of preventive and corrective maintenance activities, including mowing, site inspections, debris removal, periodic structural repairs, and removal and disposal of sediments on a 10 to 20-year clean-out cycle.

6. As an important aspect of pond maintenance, periodic sediment removal was evaluatd, based on sediment loading and pond accumulation rates observed or estimated to occur from stablilized suburban and urban land uses. Available cost information on sediment removal operations suggests a cost range of $5 to $8 per cubic yard of material removed for dry pond clean-out, and $8 to $10 per cubic yard for wet pond operations assuming either on-site disposal of recovered material or low cost disposal at a nearby disposal site. Long distance hauling or land/rubble fill disposal fees were estimated to escalate costs of operations considerably.

7. Modification to design criteria of traditional peak-shaving dry detention ponds to make them function also as Best Management Practices (BMPs) that achieve longer detention times and higher levels of pollutant removal were estimated to involve about a 10 to

12 percent increase in dry pond construction costs. Traditional wet pond designs were found to operate well as BMPs which achieved high levels of nonpoint source pollution removal in recent field and analytical studies conducted by the Virginia Polytechnic Institute and Northern Virginia Planning District Commission for COG under the EPA Nationwide Urban Runoff Program. Higher detention BMPs were not felt to require more maintenance than that identified for proper upkeep of traditionally designed stormwater management pond structures.

8. Total annualized project costs on a dwelling unit basis help portray the financial commitment associated with pond construction and upkeep over a typical 20-year planning period. Cost comparisons for hypothetical 20 acre and 100 acre drainage areas were prepared which showed significant cost savings associated with building ponds to serve larger portions of a major development. For example, estimated costs of SWM pond construction per dwelling unit for 100-acre developments were on the order of 50% less than for ponds serving 20-acre developments.

9. Looking at total pond project costs (construction and O&M) extended over a 20-year planning period, annualized project costs per dwelling unit for a pond serving a 20-acre development were estimated at about $32/D.U./year (medium density single family development) and approximately $16/D.U./year at a townhouse/garden apartment development.

Annualized project costs are lower for ponds serving 100-acre developments, with costs estimated at about $10/D.U./year for a medium density single family development and $5/D.U./year at a townhouse/garden apartment development.

10. Stormwater management programs around the country currently employ a variety of finance mechanisms to fund detention/retention basin capital construction and O&M. Local funding constraints have limited the number of public facilities funded through traditional long term loans. Public agencies must increasingly rely on cash-on-hand, employing pro-rata developer contributions, user fees, and utility charges calculated on the basis of impervious land area and/or zoning category.

11. A review of a number of stormwater management programs around the U.S. indicates a trend towards assumption of greater public agency responsibility for pond maintenance. A principal reason for this trend appears to be a desire for better enforcement and coordination of maintenance programs. There also seems to be a generally held perception among SWM professionals that it is impractical to hold private property owners responsible for the full range of maintenance functions required to keep the structures operating as designed over their useful life, particularly when major corrective or structural repairs are involved. Factors cited in this

regard include the transient nature of home ownership and instances where a loosely structured homeowners association would be ill-equipped to manage pond upkeep over the long term. Regular pond site inspections are seen as the most important minimum role for public SWM agency responsibility.

INTRODUCTION

Stormwater management (SWM) ponds, or permanent detention and retention basins, are increasingly being used in the Washington metropolitan area in conjunction with new residential and commercial development. These structures are designed to store storm runoff for specific periods after a storm event, with the objective of minimizing post-development increases in runoff. Recent local and national interest in the water quality impacts of urban stormwater pollution has focused additional attention on the pollutant removal and solids settling capabilities of these ponds. For instance, local studies of storm runoff conducted since 1976, including data collection sponsored under the EPA Nationwide Urban Runoff Program (NURP), have in most instances confirmed the multi-use benefits of SWM ponds in both controlling peak runoff as well as providing some measure of runoff pollution control.

The pond structures built in the Washington area as a result of local stormwater management programs can be categorized in several ways: first, either as "wet" or "dry" ponds and second, as either "on-site" or "off-site" structures. Structurally similar, dry ponds and wet ponds differ in that dry ponds (also called detention ponds) are designed to temporarily impound stormwater runoff for short time periods to reduce the impacts of peak runoff flows and then gradually drain down completely at an allowable release rate. By contrast, wet ponds are designed to maintain a relatively constant normal pool level and have additional storage capacity for temporary runoff storage during storms.

The majority of the SWM impoundments built to date in the Washington region have been dry detention basins. In a recent contract study conducted for COG, the Northern Virginia Planning District (NVPDC, 1980) suggested design modifications to traditional peak shaving detention basins to add to storage volumes provided and increase detention times, so that the physical and biological processes operative with such structures could achieve additional nonpoint source pollution removal. Recommended design modifications for new structures included increasing storage volumes on the order of 15 to 25% to achieve a nonpoint source (NPS) pollution storage area and extended runoff detention times of about 24 hours. Other modifications recommended by NVPDC included use of perforated risers and/or subsurface drainage for dry ponds, and increased pond length to width ratios so as to maximize the distance between pond inflow and outflow. These recommendations were later incorporated into the Fairfax County Public Facilities Design Manual for "Best Management Practices" (BMP) Facilities. The Fairfax manual also suggested that traditional wet retention ponds would be considered BMPs if the permanent body of water exceeded three times the required NPS storage volume. Figures 1 and 2 illustrate the difference between traditional detention basin and modified BMP designs.

SWM ponds are also generally categorized as either "on-site" or off-site". As the name implies, on-site structures are built on the development site and in most cases, are designed to control runoff draining only from that site. As such, these ponds are typically small (less than 5 acre-feet in size), serving drainage areas of 20 to 100 acres for residential developments, and less than 10 acres for commercial and industrial developments. The on-site pond is the structure most widely encountered and utilized in the Washington region at present. However, there has been increased use in some jurisdictions of larger "off-site" SWM ponds designed to control runoff from more than one development site. Tributary drainage areas to such ponds generally range from 150 to 200 acres. The off-site approach to runoff control presents the opportunity for several developers to divide the costs of building and maintaining a pond among themselves or to share costs with the municipality which has stormwater management responsibility. It also permits the control of runoff from previously developed tributary areas that presently have no SWM controls.

Purpose and Scope of COG Analysis

The use of both traditional SWM ponds and ponds modified as BMPs has increased significantly over the last decade. At the same time, planners and engineers in both public and private sectors have tried to develop a reasonably accurate means of assessing the costs associated with building these structures and maintaining them over their useful life. The emphasis to date has been on developing easily applied "desk top" methods for predicting pond construction and maintenance costs in conjunction with general planning-level evaluations. Considerable headway was made in this regard as a result of a 1977 detention basin study conducted for Montgomery County by the U.S.D.A. Soil Conservation Service (SCS, 1977). The SCS study, after examining construction requirements on 34 ponds built in Montgomery County, developed a set of formulas for estimating pond costs which exhibited a strong nonlinear relation between pond construction costs and volume of storage; i.e. that marginal costs decrease for each volume of storage increment.

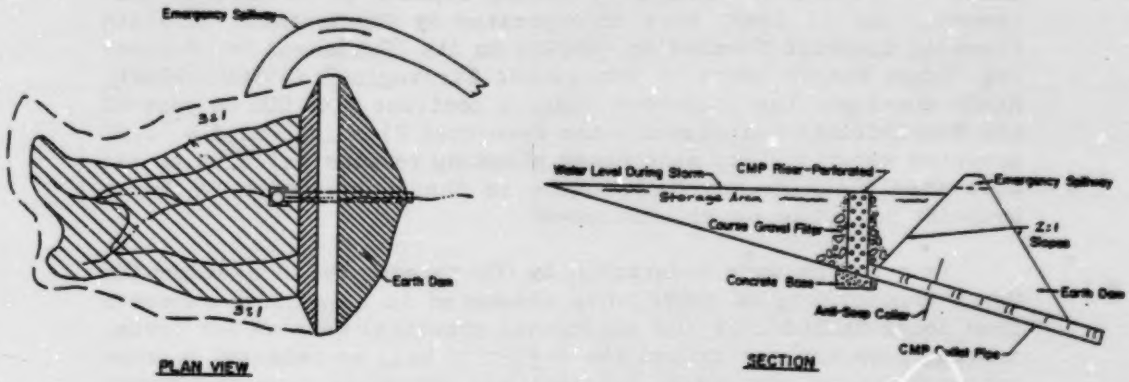
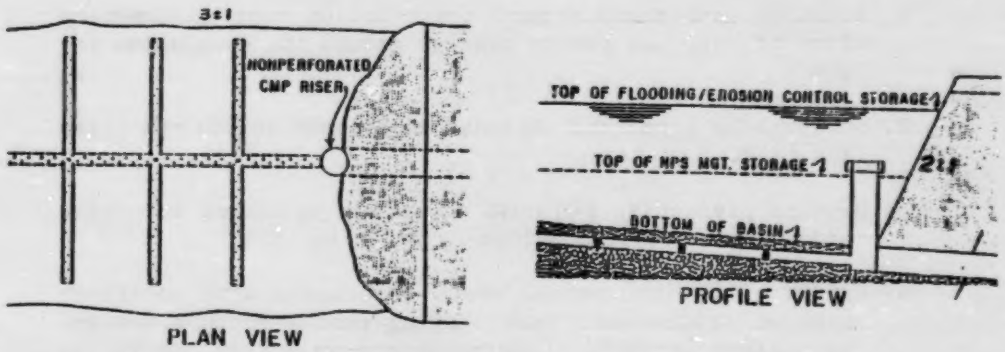

Emergency Spillway
3:1
Earth Dam
3:1
PLAN VIEW
Water Level During Storm
CMP Riser-Perforated
Storage Area
Course Gravel Filter
Concrete Base
Anti-Seep Collar
CMP Outlet Pipe
Emergency Spillway
Z:1
Slopes
Earth Dam
SECTION

Figure 1

TRADITIONAL PEAK SHAVING DETENTION BASIN

Source: Va. SWCB


3:1
NONPERFORATED
CMP RISER
PLAN VIEW
TOP OF FLOODING/EROSION CONTROL STORAGE
TOP OF NPS MGT. STORAGE
2:1
BOTTOM OF BASIN
PROFILE VIEW

Source: NVPDC

Figure 2

MODIFIED DETENTION BASIN BMP WITH SUBSURFACE DRAINS FOR NONPOINT POLLUTION MANAGEMENT

Operation and maintenance (O&M) costs were further estimated at 5 percent of construction costs. These cost formulas have been utilized in subsequent Montgomery County reports on stormwater management, and in 1980, were incorporated by the Northern Virginia Planning District Commission (NVPDC) in its "Guidebook for Screening Urban Runoff Nonpoint Management Strategies" (NVPDC, 1980). NVPDC developed the guidebook under a contract with COG as part of the Metropolitan Washington Water Resources Planning Board's "208" areawide water quality management planning responsibilities to assist area planners and technicians in their evaluation of local nonpoint pollution management needs.

Part of the work undertaken by COG through the EPA Nationwide Urban Runoff Program (NURP) has attempted to respond to requests from local technicians for additional practical data on SWM costs, drawing from sources around the region as well as relevant sources nationwide. Of particular interest was obtaining some documentation of actual field experience in the area of pond maintenance practices and associated costs. The analysis contained this report has attempted to build upon and refine the findings of the earlier SCS and NVPDC studies by examining pond construction and O&M costs in greater detail and by expanding the original data base to include data on pond costs observed through public and private sector experiences throughout the Washington region. Basic elements of COG's work included steps to:

1. Identify and compile pond construction cost information from private and public sources around the Washington region;

2. Survey both local and national experience on O&M practices and related costs;

3. Develop predictive SWM cost equations to assist in public and private sector development planning; and

4. Estimate the incremental costs associated with modification of traditional peak shaving pond structure designs to achieve improved nonpoint source pollution removal as urban "best management practices" (BMPs).

The report's principal focus is on identification of costs associated with building and maintaining "on-site" SWM structures, which continue to be the most typically constructed ponds in the Metropolitan Washington area. Resultant findings on pond construction costs are also compared, however, with a limited sampling of local "off-site" pond structures.

Report Format

Chapter I of the report discusses construction cost data findings derived from an analysis of unit costs and construction requirements for 31 representative local SWM ponds. Construction costs associated with off-site detention/retention facilities are evaluated. In Chapter II, a survey of O&M field experience is assembled and used to predict average O&M costs. Chapter III assesses what, if any, additive SWM construction and O&M costs result from pond design modifications to make the structures function as BMPs. Chapter IV concludes the report by presenting the unified capital and O&M cost picture on the basis of total annual costs and costs per dwelling unit. This final Chapter also contains some remarks on various financing considerations involved in the establishment and/or management of SWM programs.

CHAPTER I

STORMWATER MANAGEMENT POND CONSTRUCTION COSTS

BACKGROUND AND GENERAL METHODOLOGY

The primary objective of this report is to provide an up-to-date and easily applied method of predicting pond construction costs once the site characteristics of a development and pond storage volume requirements have been determined. The report builds upon earlier studies done locally on this topic, including a 1977 analysis of detention basins conducted for Montgomery County by the U.S.D.A. Soil Conservation Study (USDA SCS, 1977), which examined cost data from 34 ponds designed in the county. Costing formulas developed by SCS through this effort suggested a strong curvilinear relationship between pond construction costs and volume of storage, indicating that as volume of storage goes up, the cost per unit of storage decreases. This relationship was incorporated as a "rule of thumb" for estimating SWM pond costs. In its "Guidebook for Screening Urban Nonpoint Management Strategies", NVPDC, 1980 suggested application of the SCS equation for predicting pond construction costs, with adjustment made to account for inflation. The resulting relationship was described as follows:

$$\text{Base Construction Costs (in 1979 dollars)} = (107.1) * (V)^{0.483}$$

where V = storage capacity of detention basin in cubic feet

An allowance for planning, design, and administrative costs set to 25% of construction costs was also included to obtain total capital construction-related costs, such that:

$$\text{Total Capital (Construction) Costs (in 1979 dollars)} = (1.25) * (107.1) * (V)^{0.483}$$

$$= 133.88 * (V)^{0.483}$$

Work described in this chapter has attempted to refine and expand the data base used in the earlier SCS and NVPDC analyses by examining pond construction costs in greater detail and by extending the geographic area of the study beyond Montgomery County to include representative ponds constructed in other jurisdictions

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throughout the Washington region. In summary, the cost analysis presented here entailed:

- Selection of 31 representative ponds (5 wet and 26 dry ponds) for study from a comprehensive inventory of stormwater management structures regionwide.
- Development of a listing of individual component units typically utilized in pond construction.
- A survey of local agencies, design engineers, and construction firms to determine the range of "in-place unit costs" for each of these components.
- Application of unit cost survey findings to estimate ranges of costs for each of the 31 local ponds using known construction components.
- Development of summary descriptive statistics and predictive equations on average pond costs.

The examination was structured to focus on the construction-related aspects of pond capital costs. As such, the highly variable capital costs of land acquisition have not been included in the present analysis.[1] Cost estimates presented also assume that the ponds are constructed exclusively for peak runoff control purposes. As such they do not account for any incremental costs or cost savings that may be achieved through conversion of construction site sediment basins to permanent detention/retention basins.

The following sections discuss the methodology and findings of COG's construction cost analysis in greater detail.

---

[1] A simple methodology for computing land area requirements for on-site structures is presented in the SCS Montgomery Co. Study (SCS, USDA, 1977):

Drainage Area (acres)	Land Requirements (acres)
0 - 50 acres	$(V)/2$
50 - 100 acres	$(1.1)(V/0.4d)$

Where V = storage capacity in ac-ft; d = max. depth of ponding, in ft. For computation of capital costs, readers should note that in many instances jurisdictions conducting site plan review will view land set aside for SWM ponding as open space. Land costs associated with ponds could thus offset other costs incurred in overall site plan development.

DATA COLLECTION

Stormwater Management Structure Inventory

In early 1980, COG inventoried existing stormwater management structures in the Washington region. Approximately 1,600 structures were identified, consisting primarily of retention/detention basins (wet and dry ponds). Of these, 75 structures were reviewed more closely to determine their utility as potential Best Management Practice (BMP) study sites under the Washington NURP project. When available, information on the design characteristics of each structure was obtained from the managing agency or builder. Upon receipt and review of this information, 31 ponds (5 wet and 26 dry ponds) -- judged to be most representative of local SWM ponds and the cross-section of residential and commercial land uses found in the region -- were selected for detailed cost analysis. A characterization of the 31 structures is presented in Table 1.

Development of Unit Cost Data

A first step towards estimating pond construction costs involved the development of a comprehensive list of common pond components or construction requirements. Review of design plans for the 31 ponds selected for study resulted in compilation of a list of 200 unit construction components (excavation, stabilization, anti-seep collars, drains, pipe, trash racks, etc.), each identified by commonly used units of measurement. Next, with the assistance of the National Association of Homebuilders, the Northern Virginia Builders Association and Suburban Maryland Homebuilders Association, COG conducted a survey of local public agencies, private developers and engineering-consulting firms with experience in local pond construction to receive independently prepared estimates of the unit costs for each component listed. The cost figures requested were "in-place unit costs" (1980 dollars) defined as the price of individual components installed at the pond site. Appendix A presents a sample of the COG survey form and listing of pond components for which unit cost data were collected.

Twelve local organizations responded to the COG Unit Cost Survey, representing a cross-section of private and public sectors as indicated in Table 2.

Table 1

CHARACTERISTICS OF PONDS SELECTED FOR COST ANALYSIS

DRAINAGE AREA CONTROLLED			DRAINAGE AREA LAND USE			POND STORAGE CAPACITY		
On-Site Drainage Area Category (acres)	Total Number of Ponds	Percent of Total	On-Site Land Use	Total Number of Ponds	Percent of Total	Volume of Storage (cu ft) at Crest of Emergency Spillway	Total Number of Ponds	Percent of Total
1-5	8	26%	Large Lot Single Family	3	10%	2,000-10,000	5	16%
6-10	5	16%				10,001-20,000	4	13%
11-15	2	6.5%	Medium Density Single Family	6	19%	20,001-30,000	1	3%
16-20	2	6.5%				30,001-40,000	4	13%
21-30	1	3%	Townhouse/ Garden Apt.	9	29%	40,001-50,000	3	10%
31-50	4	13%				50,001-70,000	3	10%
51-75	4	13%	High Rise Apt.	1	3%	70,001-100,000	2	6.5%
76-100	1	3%				100,001-150,000	5	16%
101-150	3	10%	Commercial/ Industrial	12	39%	150,001-200,000	1	3%
151-200	-	-				200,001-400,000	1	3%
201-350	1	3%				400,001-800,000	2	6.5%
TOTALS	31	100%		31	100%		31	100%

a/Also includes high impervious land uses such as parking lots.

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Table 2
UNIT COST SURVEY RESPONDENTS

Private Developers

Burke Center Partnership; Fairfax, Va.
David Smith Builders; Developers; Gaithersburg, Md.
Democracy Development Company; Potomac, Md.

Consulting Engineers

Dewberry, Nealon and Davis; Fairfax, Va.
Oyster-Imus-Petzold, Inc.; Wheaton, Md.
Warring Associates; Hyattsville, Md.

Public Agencies

Maryland-National Capital Park and Planning Commission
Washington Suburban Sanitary Commission
Rockville Department of Public Works
Montgomery County Department of Transportation
Fairfax County Division of Design Review
Fairfax County Division of Inspection Services

Information supplied by the twelve respondents was then tabulated into a "Regional Unit Cost List", included here as Appendix B. All totaled, the survey generated approximately 2,000 separate estimates of in-place unit costs.

APPLICATION OF UNIT COST DATA TO SELECTED PONDS

Close review of site plans and engineering drawings for the 31 ponds under analysis allowed identification of the specific construction requirements or components of each pond. Once pond components were determined, unit cost survey results were then applied to estimate total construction costs for each pond using a common methodology.

Information identified and calculated from site plans of each structure included:

- Total cut and fill needed in construction of pond,[2]
- Area of land to be cleared,[3]
- Area of land to be cleared and grubbed,[4]
- Area of land to be restabilized after pond construction;[5] and,
- Volume of storage at the crest of the pond's emergency spillway.

Engineering drawings for individual ponds were consulted to identify specific information on type and sizing of structural components and hardware, such as endwalls, risers, etc. In instances where detailed design drawings were not available, engineering judgement was used to identify construction components. This process resulted in preparation of a complete listing of individual components for each of the 31 ponds.

Twelve separate construction cost estimates for each pond were then calculated by applying and totaling the in-place unit costs provided by each of the 12 survey respondents to the listing of individual pond components compiled above. In cases where a respondent provided no cost estimate for a particular component, a mean value calculated from other survey responses was utilized.[6] The resulting data base thus consisted of 12 estimates of total pond construction costs for each of the 31 ponds, or a total database of 372 estimates for subsequent statistical analysis.

Table 3 provides an illustrative example of the kind of unit cost computation utilized to estimate construction cost for one pond.

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[2] Common cut and fill were assumed to balance out over the total subdivision or development site.

[3] The area to be cleared was assumed to be equal to twice the pond surface area at the 10-year flood level (to account for pond area plus a small surrounding easement area).

[4] Pond embankment and emergency spillway. Not included in calculation of cleared area (3) above.

[5] Area cleared plus area cleared and grubbed minus the normal water surface for wet ponds.

[6] Substitution of mean values was confined to such items as pipe or trash racks and not those items comprising the bulk of total pond costs, such as compacted fill, stabilization.

Table 3
SAMPLE ESTIMATE OF POND CONSTRUCTION COSTS
BASED ON UNIT COSTS
(180,000 Cu Ft Dry Pond)

Construction Component	Unit Cost ($) (in place)	Quantity Needed	Total Cost ($) (Dec. 1980)
Clearing	$2,729/AC	1.77 AC	$4,830
Clearing and Grubbing	3,293/AC	0.33 AC	1,087
Common Excavation	2.60/AC	2,185 AC	5,681
Hydro Seeding	1,853/AC	1.7 AC	3,150
Compacted Fill	3.30/CY	2185.0 CY	7,211
WSSC Endwall (21")	694/EA	2.0	1,388
Reinforced Concrete Pipe-Class IV (21")	33/LF	93.0 LF	3,069
Concrete Flume	35/SY	388.0 SY	13,580
Anti-Seep Collar (21")	260/EA	3.0	780
Total Construction Costs			$40,776

a/ Unit costs shown in this sample are representative only.

b/ "In-place unit costs" are defined as the price of a pond component installed at the pond site.

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CALCULATION OF AVERAGE POND CONSTRUCTION COSTS

Compilation of the pond estimates described above permitted development and analysis of descriptive statistics for each pond and the database as a whole. Examination of the distribution of cost estimates for each pond revealed that the mean and median cost were approximately equal, suggesting a relatively normal distribution among the twelve separate cost estimates developed for each individual pond. For the most part, the range covered by cost estimates for individual ponds fell within plus or minus 2 standard deviations from the mean. In some cases, the observed estimates were concentrated near the mean. The highest and lowest of the 12 estimates per pond did, however, sometimes fall outside the range of plus or minus three standard deviations from the calculated mean. To determine whether these estimates should be treated as outliers, a sample calculation was performed which removed any estimates beyond 3 standard deviations from the mean. Removal of these values (± 3 std. dev.) had little effect on the mean or median due to the normal distribution of costs. Based on these findings, it was decided to utilize the entire database, and the mean cost of each pond was chosen as the best indicator of central tendency from which to develop a predictive equation for average pond capital construction costs.

Relationship Between Average Pond Costs and Volume of Storage

As previously noted, the earlier SCS and NVPDC studies suggested formulas for estimating SWM (and/or BMP) pond costs based upon the correlation between average pond costs and volume of storage. To determine whether a similar correlation existed for the group of ponds assessed in this study, regression analyses were performed to test the linear or nonlinear relationship between the average or mean costs generated above and the known volume of storage for each of the 31 ponds. In general, the analyses revealed only a moderate linear relation (showing a Pearson R value of 0.70), without excluding some outlying cost values. However, a nonlinear analysis produced a good correlation with the entire database, achieving a Pearson R value of 0.84.

Figure 3 presents the line of best fit against the scatter of pond construction cost means. As indicated, the equation for the line of best fit can be expressed by the equation:

$$\text{Base Construction Costs} = 77.4 * (V)^{0.51}$$

(in Dec. 1980 dollars)

where V = design storage volume

This equation was judged to be suitable for predicting average pond construction costs. Figure 4 plots the predicted versus observed costs, revealing a relationship approaching 1:1. From this it can be assumed that the internal bias of the predicted equation is relatively small.

An additional allowance, equal to 25 percent of construction costs, was considered appropriate to provide for planning, design, administration and other construction-related contingencies,[7] changing the original equation to:

$$\text{Total Construction-Related Costs} = (1.25)(77.4) * (V)^{0.51}$$

(in Dec. 1980 dollars)

$$= 96.8 * (V)^{0.51}$$

The two equations are depicted in Figure 5. As can be seen, the costs of construction per volume of storage generally decrease with increasing storage volume. From the data, one can see the economies that might be realized if, for example, a 110,000 cu ft detention basin (construction cost estimate of $28,800) could be sited and constructed to serve an entire 40 acre drainage of townhouse/garden apartments as compared to construction of four 27,500 cu ft basins serving ten acre sub-parcels of the drainage at a combined construction cost of $56,900.

Comparison with 1977 SCS Estimates

The 1977 SWM cost study conducted by SCS for Montgomery County also identified a strong nonlinear relationship between construction costs and volume of storage. SCS suggested use of an equation to predict construction costs, where:

$$\text{Base Construction Costs} = 85 * \text{Volume of Storage}^{0.483}$$

in 1976 dollars
(exclusive of land)

A plot of this equation, when adjusted for inflation to the December 1980 base used by COG (Engineering News Record, Baltimore Construction Cost Index), shows an almost identical slope when compared to the COG predictive line (Figure 6). This similarity is encouraging, given the different data bases and independent approaches used in their derivation. It is also noted that the average pond cost projections developed in the COG analysis tended to be generally lower (on the order of 10 percent) than the Dec. 1980 adjusted SCS values.

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[7] The 25 percent allowance appears to be consistently used in the Washington area for capital improvements computations and in local SWM studies, and was utilized by both NVPDC (1980) and SCS (1977). The allowance also appears to be consistent with literature values presented in other construction project management guidance reviewed, with suggested values ranging from 18 to 31 percent.

Figure 3

LOG PLOT OF AVERAGE STORMWATER MANAGEMENT POND CONSTRUCTION COST ESTIMATES
VS.
VOLUME OF STORAGE

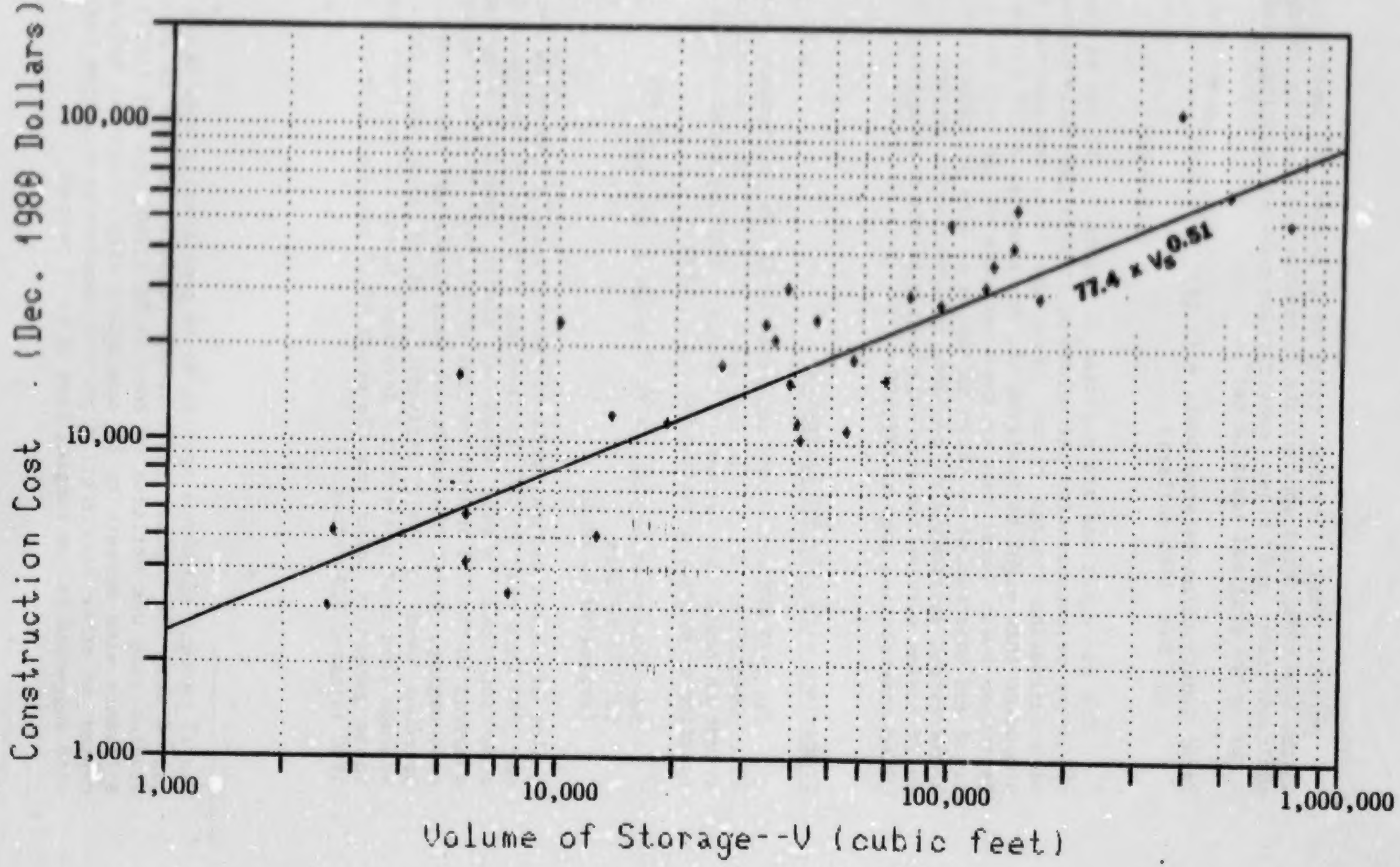

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Figure 4

OBSERVED VS. CALCULATED
AVERAGE STORMWATER MANAGENENT POND CONSTRUCTION COSTS

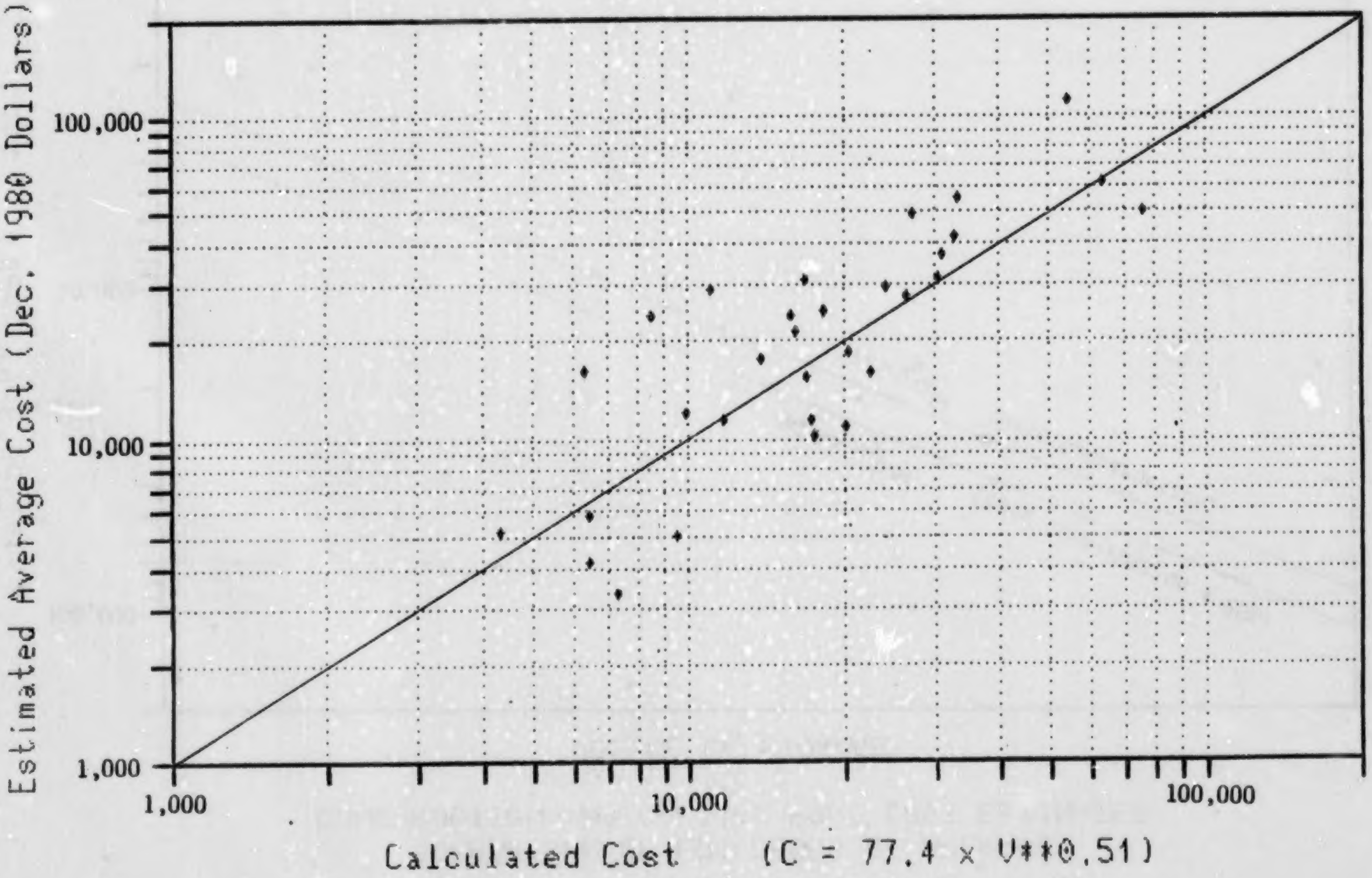

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Figure 5

COMPARISON OF LOG PLOTS OF AVERAGE CONSTRUCTION AND CAPITAL POND COST ESTIMATES VS. VOLUME OF STORAGE

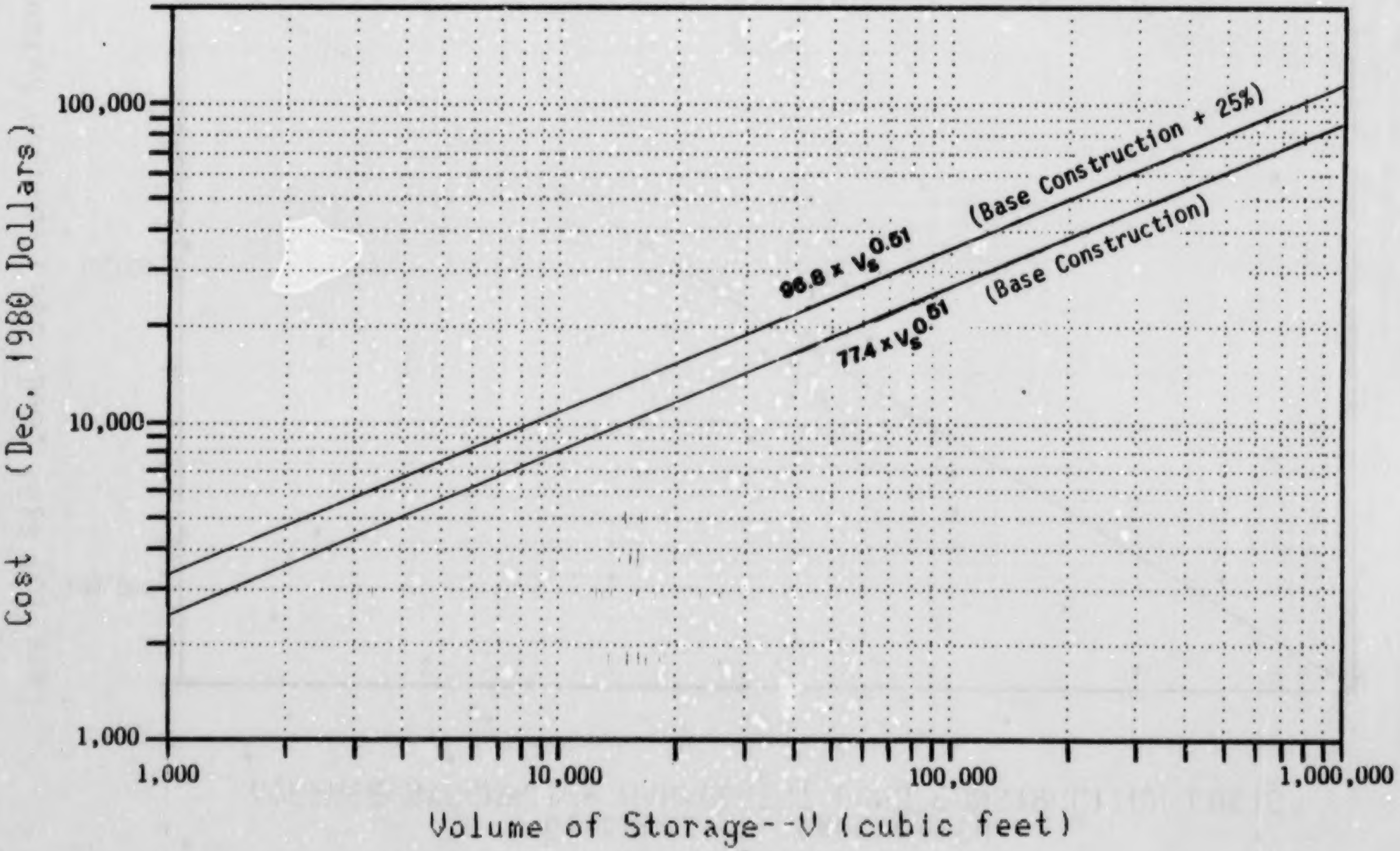

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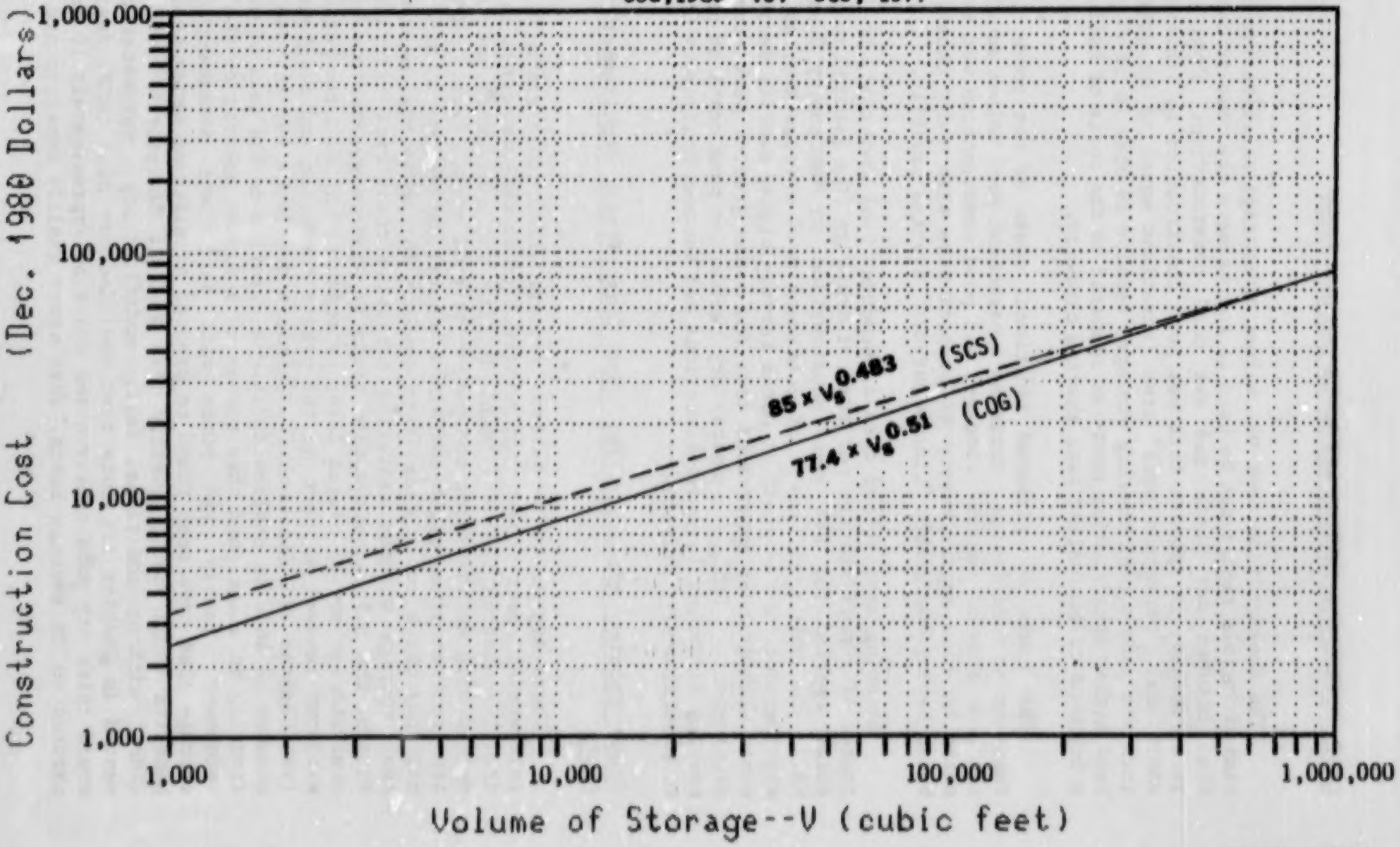
Figure 6

LOG PLOT OF AVERAGE STORMWATER MANAGEMENT POND CONSTRUCTION COST ESTIMATES
VS.
VOLUME OF STORAGE
COG,1983 vs. SCS, 1977



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COST DIFFERENCES BETWEEN WET PONDS AND DRY PONDS

The construction cost vs. volume of storage relationship presented in this report can be used to approximate the cost differential between dry ponds and wet pond construction. From this relationship, it appears that wet pond construction to achieve an additional "permanent pool" area (sometimes equal to or greater than the pond's peak shaving storage) results in some 26 to 47 percent higher construction costs as compared to the costs of building a dry pond of equivalent peak shaving capacity.

The range in estimated additional costs of wet ponds is a function of pond design. Assuming a permanent pool volume equal to the peak shaving control storage, wet pond construction was estimated to cost approximately 40 percent more than a dry detention basin having comparable "single purpose" storage capacity.

Assuming as a second case a permanent pool area equal to 0.50 inches of runoff storage per acre of drainage (the general rule of thumb applied for wet pond construction in Montgomery County, Md.), the additional costs of permanent pool storage are, as one might expect, not as great at ponds serving higher density developments with greater impervious area and hence greater peak storage requirements. Table 4 compares dry versus wet pond costs at ponds serving different land use situations and assumes Montgomery County general design criteria.

Other Factors Affecting Wet Pond Construction Requirements and Costs

There appear to be several factors which could minimize the incremental costs of wet pond construction or make wet ponds an attractive alternative investment despite the additional costs involved with establishing the permanent pool area. First, certain construction sites might contain a natural depression in site topography which could facilitate ponding for additional permanent pool storage without requiring extensive additional excavation. Second, the initial excavation costs to achieve greater permanent pool storage may be offset later by reducing the need for periodic sediment removel as part of the pond's operation and maintenance (see Chapter III discussion). Third, a developer may in some instances be able to realize additional profits on the sale of units fronting on a wet pond that serves as a visual amenity to the development. Lastly, wet ponds with sufficient permanent pool storage also have been found to produce significant water quality benefits which could qualify them as Best Management Practices (BMPs) without additional design modifications. Estimates presented in Chapter III note that modified dry pond (BMP) designs could raise dry pond construction costs by approximately 10 to 12 percent on an average basis. When water quality benefits are in-

Table 4

COMPARISON OF WET VERSUS DRY POND CONSTRUCTION COSTS (a)

Land Use	Peak-Shaving Storage (b) cubic feet	Permanent Pool Area cubic feet	Total Wet Pond Costs (a)	Percent Cost Increase Attributed to Permanent Pool Storage
20-Acre Medium Density Single Family (25% impervious)	32,000	36,300	$22,610	47%
20-Acre Townhouse-Garden Apt. (40% impervious)	56,000	36,000	26,300	29%
100-Acre Medium Density Single Family (40% impervious)	180,000	181,500	52,900	43%
100-Acre Townhouse-Garden Apt. (40% impervious)	310,000	181,500	61,900	26%

(a) Base Construction Costs, based on COG volume storage-construction cost projections. Rounded to nearest hundred dollars.

(b) Montgomery County peak shaving requirements for maintenance of 2-year design criteria storm at predevelopment levels of approximately 0.6 to 0.8 inches/hour. Permanent pool area based on 0.50 inches runoff storage per acre of drainage.

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cluded as storage objectives, such comparisons appear to make additional costs of wet pond storage more competitive from a cost-effectiveness standpoint.

COMPARISON OF ON-SITE STRUCTURES WITH OFF-SITE OR REGIONAL STRUCTURES

Independent construction cost estimates[*] for 12 "off-site" SWM ponds in Montgomery County, ranging in storage volumes from 63,000 to 3,000,000 cubic ft, were evaluated to determine how their costs compared on a volume storage basis, and what, if any, comparisons could be drawn with the on-site pond construction cost estimates generated in the COG analysis.

Recognizing that care should be taken in making such comparisons with limited data, examination of the off-site construction costs along with the COG cost projections suggested some interesting cost-volume relationships. A plot of the engineering cost estimates for the 12 ponds generally showed, as one might expect, that some unit cost economies are realized with larger volumes of storage. For example, the data indicated that cost-savings would accrue from choosing to build a centralized off-site facility of say 500,000 cubic feet at an estimated cost of $200,000 (Montgomery County DEP), as compared to building 15 individual on-site ponds (33,300 cu ft each) at a cost of $15,700 per pond (COG estimate), resulting in a combined total of $235,500.

At the same time, costs for the off-site ponds appeared to rise sharply at the upper end of the ponds sizes considered, appearing to eliminate such a clearly defined cost advantage. For example, construction of an off-site pond with over 2,000,000 cubic feet of storage (at a construction cost estimate of $1,000,000; Montgomery Co. DEP) does not represent a cost-savings over the construction of four 500,000 cu ft ponds at $200,000 each (DEP estimate) or construction of twenty 100,000 cu ft ponds at $28,000 each (COG construction cost estimate), totalling $560,000. Presumably the costs of the major off-site facilities may be driven up in some cases due to more stringent structural requirements demanded of major SWM impoundments located in urban areas where dam failure could result in safety hazards or damage to residential property. It is also not uncommon to find that construction of larger off-site facilities in stream valley areas will require costly reallignment of sewer lines, and in some cases, replacement of water mains.

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[*] Engineering estimates supplied by Montgomery County Department of Environmental Protection.

While such cost comparisons are interesting, it must be pointed out that they are quite preliminary. More detailed analyses appear warranted to assess any trade-offs that might be available in the selection and sizing of a SWM pond structure to fit the needs of a particular drainage area or watershed. This analysis would, of course, have to consider the size of drainage area, site specific topography and soil characteristics, number of dwelling units served, land acquisition costs, and the effectiveness of the projects in reducing stormwater problems associated with streambank erosion and nonpoint source pollution. One important cost-benefit tradeoff suggested in current literature is that siting constraints for a major off-site facility may mean that a certain distance of stream channel upstream of the facility that would normally be protected by on-site controls would not be afforded flooding and erosion control. Another concern voiced in regard to off-site/regional facility construction involves the "conveyance costs" associated with extensive engineering of the upstream channel network or employment of costly pipe storm drainage systems (Personal communication, M-NCPPC, June, 1983).

Financing considerations may also become key factors affecting off-site construction. For example, initial capital outlays of public funds for a large scale pond may be substantial, despite private developer contributions. It may take a long time for a locality to recoup this investment if new developments in the drainage basin are slow to buy-in to the pond's storage capacity in lieu of on-site requirements. On the other hand, several SWM studies have suggested that public agencies may realize some cost savings from being able to centralize public operation and maintenance functions for the off-site facility (Gannett Fleming Corddry and Carpenter, Inc., 1975; Lynard 1980).

CONCLUSIONS

A statistically acceptable relationship between pond construction costs and volume of storage was determined on the basis of the COG unit cost constuction analysis. This relationship is expressed by the equation:

$$\text{Base Construction Costs} = 77.4 * (V)^{0.51}$$

where V = design storage volume. and

$$\text{Total Construction-Related Construction Costs} = (1.25)(77.4) * (V)^{0.51}$$
$$= 96.8 * (V)^{0.51}$$

in instances where an additional cost allowance is made for planning, design, administration, and contingencies equal to 25 percent of base construction costs.

Application of the construction cost projection is intended to assist in making broad estimations of pond costs, such as in conjunction with the comparative studies utilized in the master planning process, water quality investigations in a particular watershed, or as an aide to decision-makers in evaluating the overall financial impacts of stormwater management projects. Readers who are trying to determine the more specific costs associated with pond construction at a particular commercial or residential site are cautioned to be aware of the inherent limitations of the general cost/volume of storage projections, and should thus consult more detailed engineering estimates, if available.

Adjustment for Inflation

The in-place unit costs used in developing the construction cost equation presented in this report are December 1980 prices. To account for inflation, readers can utilize the Cost Index published periodically in the "Engineering News Record" to update the cost equation to the time period desired.

CHAPTER II

OPERATION AND MAINTENANCE COSTS

BACKGROUND AND GENERAL METHODOLOGY

A prime consideration in developing a sound stormwater management (SWM) program is the inclusion of provisions for proper maintenance of stormwater management structures to ensure that they function properly and safely over their useful life. Pourtner (1980) and others in the stormwater management field have pointed out the importance of maintenance programs to the long-term effectiveness of control structures. Clogged pond inlets and outlets can significantly alter the nature of flow regulation and pollutant removal provided by a SWM structure. Neglected ponds can become unsightly and unsafe.

Because permanent residential and commercial detention ponds are relative newcomers to the field of stormwater management -- many of them constructed within the last 3 to 10 years -- there is only rudimentary documentation available concerning operation and maintenance (O&M) requirements under actual field conditions. While current literature is attempting to provide better quantification of program requirements (e.g., American Public Works Association, 1981), information available still tends to be quite generalized and theoretical. There is little clear-cut itemization of costs pertaining directly to detention/retention programs as distinct from general flood control and storm drainage programs. Planners and engineers involved in SWM pond implementation are left to making rough approximations of the potential costs that might be incurred by a jurisdiction, developer, or more likely, a homeowners association over the structure's useful life of perhaps 50 years.

As was the case in the assessment of pond construction costs, both NVPDC (1980) and SCS (1977) recognized the need to incorporate O&M cost projections into pre-development SWM planning. Both suggested that, as a general rule, project budgets for O&M set at 5 percent of total pond construction costs should suffice to cover

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[9] For modified detention pond BMPs, NVPDC (1980) suggested an annual O&M cost projection set at 6.25 percent of construction cost. See Chapter III for discussion of additional construction and O&M costs of these structures.

annual O&M costs for single-purpose detention basins (in drainage areas less than 30 acres).[9,10] This 5 percent estimate assumed allowance for at least 1 minor site inspection per year and 1 major maintenance visit every 5 years to dispose of accumulated and debris that might affect a pond's viability.

Under its NURP project, COG staff has conducted research to expand the data base on actual O&M costs incurred in the field, and thereby permit a more detailed analysis of such costs than attempted under the earlier SCS/NVPDC work. The objective of this work was to develop additional guidance on general SWM pond maintenance considerations which might be useful locally and nationally in the estimation of program and cost requirements for effective long-term operation of SWM facilities. COG's investigation involved a review of current SWM literature as well as extensive discussions with technicians that are responsible locally, and elsewhere, for maintaining SWM ponds. The principal focus of this effort involved identification of the nature and frequency of typical O&M tasks and average O&M costs on a per structure basis. Resulting estimates of O&M costs were then analyzed along with pond construction cost data developed in Chapter I to identify "rule of thumb" relationships between pond construction and annual O&M costs on the basis of percentage of construction costs.

DATA COLLECTION

Data collection involved both a review of current literature as well as direct discussions with private and public sector individuals involved in SWM planning either locally or outside the region. As part of this effort, approximately 70 phone and letter contacts were made. Eighteen of those contacted provided written material on O&M tasks and costs. Of these, only six sources forwarded information which directly lent itself to the analysis of maintenance for on-site SWM pond comparable in size and maintenance requirements to those generaly found in the Washington region. COG's analysis was restricted to ponds having a total maintained acreage of between 0.5 to 10 acres.[11] By necessity, this criterion excluded from consideration information received on some very large ponds built as flood control structures (Los Angeles County Flood Control District; Denver Urban Drainage Control District), and some extremely small on-site ponds (Marks, Fairfax County, 1979). The six organizations whose data were utilized by COG are listed in Table 5.

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[10] SCS suggested that O&M costs would drop below the 5 percent estimate for drainage areas greater than 30 acres.

[11] "Maintained acres" represent surface area of the pond (wet and dry) plus the acreage immediately adjacent to the pond that is maintained.

Table 5
ORGANIZATIONS UTILIZED IN O&M ANALYSIS

Local:Washington Metropolitan Area

Department of Parks and Recreation
City of Rockville, Md.

Parks Department
Maryland-National Capital Park and Planning Commission,
Montgomery Co., Md.

Magruder Associates
Rockville, Md.

Non-Local

Department of Engineering
City of Sterling Heights, Michigan

Department of Public Works
City of Troy, Michigan

Waterworks, Waste & Disposal Department
City of Winnepeg, Canada

In aggregate, the data accepted for analysis encompassed six separate maintenance programs on a total of 198 ponds, involving approximately 680 maintained acres. (A complete listing of all contacts made in conducting this investigation is presented in Appendix C.)

Reported Maintenance Tasks

Information collected suggests that pond maintenance generally falls into one of two categories. "Routine" maintenance involves tasks performed on some regular basis during the year and is viewed as preventive in nature. Routine tasks include site inspections and other tasks oriented to maintaining pond appearance or controlling minor nuisances. Such tasks would include grass maintenance or mowing, and removal of small quantities of trash and debris.

"Non-routine" tasks pertain to major maintenance visits, specifically to correct structural problems or remove long term accumulations of sediment and debris. These non-routine tasks, conducted once over a specified period of years, are aimed at correcting problems which might reduce the pond's effectiveness or structural integrity.

Table 6 indicates the maintenance activities reported by the six information sources which provided the O&M cost information used in this report.

Presented below is a discussion of the nature of activities which would appear to have application to on-site SWM pond maintenance programs in the Washington region. This discussion is drawn from information supplied by local agency staff involved in SWM activities, current technical literature, and from contacts with a number of public SWM agencies outside of the region. In cases where certain reported maintenance activities would appear to have less application to Washington area SWM programs, appropriate clarifying remarks are presented.

Routine Maintenance

1. Site Inspections

Scheduled, periodic site inspections were viewed as important "preventive maintenance" to recognize potential structural maintenance needs. Routine inspection items include checks for: obstruction of various stage/outlet controls, outlet channel conditions, nuisance debris, settling of dam, woody growth on dam, rodent damage, seepage, and pipe deterioration. Sterling Heights, Michigan conducts inspections on the most frequent interval reported -- on a bi-weekly basis. American Public Works Association, 1981 suggests a frequency as local experience shows necessary; "perhaps monthly as a minimum".[12]

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[12] "Urban Stormwater Management," Special Report No. 49, American Public Works Association, Chicago, Illinois, 1981, p. 217.

Table. 6

REPORTED POND MAINTENANCE ACTIVITIES

	LOCAL WASHINGTON AREA			NON-LOCAL		
	Public		Private	Public		
MAINTENANCE CATEGORY	Rockville, MD.	M-NCPPC	Magruder Assoc.	Sterling Heights, MI	Troy, MI	Winnepeg, Canada
ROUTINE						
Site Inspections	x	x		x	x	x
Grass Maintenance	x	x	x	x	x	x
Debris Removal	x	x	x	x	x	x
Bank Stabilization	x	x		x	x	
Weed Control	x			x	x	x
Algae Control	x	x				x
Insect Control					x	x
Forebay Cleaning	x	x		x	x	x
Fence Repair		x		x	x	
Program Administration	x	x		x	x	
Pump Repair				x	x	x
Electrical Repair				x	x	x
NON-ROUTINE						
Sediment Removal		x				
Pipe Replacement		x				
Regrading				x	x	
Access Road Maintenance						x

2. Grass Maintenance or Mowing

A requirement for periodic mowing was the task most uniformly reported by SWM organizations, although the requirement was directly dependent on the location of the pond structure and its intended appearance. Ponds located in residential subdivisions, shopping districts, and urban parks required frequent mowing of storage area (dry ponds), embankments and surrounding grassed areas (wet and dry ponds) in an effort to maintain a manicured appearance in conformance with surrounding land use. Mowing in these instances was reportedly conducted 8 to 14 times a year. Mowing frequency increased to bi-weekly during wet seasons and generally was discontinued during the late fall and winter months. Use of fertilizer was generally reported to maintain adequate grass cover. By contrast, a number of the ponds maintained by Maryland-National Capital Park and Planning Commission and the City of Rockville are in forested parkland or natural settings and hence require no mowing.

3. Debris and Litter Removal

Periodic removal of tree limbs and an assortment of "floatables" and other debris trapped in and around the basin was uniformly reported as a preventive maintenance function and means of maintaining pond appearance. (This debris accumulation is not entirely storm-related. Littering and dumping of leaves, mattresses, and other has been observed in ponds in Northern Virginia and Montgomery County). Organizations reported that minor debris and litter removal was usually conducted at the same time as grass maintenance and by the same maintenance crew. Regular scheduling of this task was felt to avoid potential outlet stoppages. Sterling Heights, Michigan recommends an initial spring clean-up of debris following the winter period.

4. Bank Stabilization

Minor erosion, loss of desired vegetative cover, and movement of riprap are maintenance problems routinely reported. Small scale corrective measures noted include replacement of small amounts of bank fill, re-sodding, reseeding, and replacement of riprap or other material designed to prevent shoreline deterioration. Indications are that riprap used at inflow and outflow points as energy dissipators may also have to be replaced periodically.

5. Weed Control

Physical removal or cutting of objectionable weeds growing in pond shallows was practiced by 4 of the 6 reporting organizations. A careful distinction was suggested between objectionable weeds and more desirable species with valuable aesthetic or beneficial properties. Winnepeg, Canada reported that a group of residents demanded a halt to periodic city harvesting of cattails growing in the ponds, asserting that the plants were desirable and provided waterfowl habitat. In addition, recent NURP-sponsored studies of wet ponds strongly suggest that in-pond vegetation (algae, cattails, and other rooted aquatics) can enhance natural removal of influent pollutants (Personal communication, NVPDC, 1982).

6. Program Administration

The public agencies involved in pond maintenance almost uniformly cited administration as an element of their O&M programs. Where maintenance to date has largely consisted of grass maintenance, program administration has been relatively minor, confined to scheduling of mowings and supervision of part-time help. Programs like the one in effect in Sterling Heights, on the other hand, entail fairly extensive record-keeping on some 55 city-owned or maintained ponds, including handling periodic billing of private property owners when the City has had to step in to perform corrective maintenance. Contract bidding and oversight hence are a part of the City's overall program administration.

The City of Rockville, which in the last three years has assumed maintenance responsibility for approximately 27 ponds, expects its administrative requirements to increase in future years.

7. Insect or Mosquito Control

Two organizations reported control requirements. Troy, Michigan utilizes chemical applications; Winnepeg, Canada stocks city maintained ponds with fish which feed on mosquito larvae. In the Washington area, insects do not appear not to be a major nuisance problem, with none of the local organizations reporting insect control as a principal pond maintenance function. Improved pond design to maintain pool depth and adequate drainage to avoid soggy areas are thought to be effective deterents to insect/mosquito infestations.

8. Algae Control

Physical removal of algae as well as chemical applications were reported by three organizations to reduce standing algal crop in wet ponds. Algae growth can be expected, given the ample supply of nutrients reaching the ponds. Again, recent Washington NURP data suggests that some algal growth can aid in natural uptake and removal of pollutants.

Odor problems commonly associated with algal decay and quiesient ponds did not appear to be evident at the ponds monitored under the Washington area NURP project. (Personal communication, NVPDC, 1982).

9. Fence Repair

In some localities, fencing is required to reduce the structure's potential hazard as an "attractive nuisance" and to deter entry of children for reasons of safety. Periodic fence repair was reported by three organizations.

Fence repairs are not commonly encountered in the Washington region because fencing is generally not required by local ordinances for public safety purposes. A majority of Washington area jurisdictions leave the decision to install a fence up to individual property owners, based on site specific considerations or concerns about liability. A fencing ordinance recently adopted by Prince William County, Va. is oriented to preventing entry of children under 4 years of age. The ordinance requires fencing of all ponds located near congested residential areas. Wet ponds, dry ponds which detain stormwater for longer than 2 hours, and ponds with side slopes steeper than 3:1 may also require fencing, regardless of location.

It should be noted that a number of observers believe that fences may themselves serve as attractive nuisances by presenting older children with an irrestible challenge to climb and enter the facility.

Non-Routine Maintenance Activities

Information suggests two non-routine maintenance tasks which require major maintenance visits once over a long term period:

1. Structural Repairs and Replacement

Inspection of structural pond components may indicate need for replacement of corrogated metal pipes subject to deterioration over time. These include pipe spillways and endwalls. The Maryland-National Capital Park and Planning Commission reported one such major maintenance visit per pond every 12 years, at a cost of $350 per pond. Corrogated metal risers have a design life of approximately 25 years, and concrete risers are projected to last 30-50 years. (Personal communication, P.G. County Public Works).

2. Sediment and Debris Removal

Stormwater management officials anticipate that sediment removal will be a major maintenance function associated with both dry and wet ponds. Clean-out operations are intended to maintain flood storage volume at close to design levels, and also to eliminate build-up of sediments which might induce unwanted plant growth, create shallow standing water favorable to mosquitos, or detract unduely from pond appearance.

Unfortunately, there is little documentation available on the frequency and magnitude of clean-out operations associated with post-development detention/retention SWM programs which could help identify expected storage depletion rates under a range of field conditions and thus assist in SWM program planning. This is primarily due to the fact that on-site retention/detention programs are relatively new and hence have not yet required major sediment removal operations. Another reason is the relatively low sediment loading rates observed in runoff from stabilized urban land uses (ranging from 0.12 - 0.33 tons/ac/yr in comparison with loading rates of 50 - 60 tons/ac/yr which are typical of uncontrolled construction site runoff in the metropolitan Washington region (NVPDC, 1980). A more complete discussion of sediment removal and disposal operations, along with some estimation of costs, is provided later in this chapter.

Comparison to National Survey

The routine and non-routine SWM pond maintenance functions identified above as being applicable to Washington area on-site SWM programs also appear to be generally consistent with those reported in a recent national survey. In a 1980 American Public Works Association polling of 219 public agencies, common pond maintenance problems were identified and noted (APWA, 1981). The six most prevalent maintenance problems rated as most severe were weed growth, grass maintenance, bank deterioration, sedimentation, mosquito control, and outlet stoppages.

Reported Maintenance Costs

Table 7 displays the annual O&M costs for pond structures as reported by the six organizations providing cost data on their stormwater management program.[13] Weighted averages of both costs per maintained acre and costs per structure were calculated based on the number of ponds in the program, average pond size, and average size of maintained area. Excluding regional differences between programs, average annual O&M (exclusive of sediment removal) are calculated at $286 per maintained acre, and $982 per structure.

Looking at differences between individual local and non-local programs (Table 8), it can be seen that differences in maintained area size has an appreciable effect on total annual costs. Costs per structure are higher for the non-local programs, because of the larger size of maintained areas. Likewise, some economies are apparent for the non-local programs on a cost per maintained acre basis ($273/acre (non-local) versus $374/acre for local programs).

Table 7

REPORTED SWM POND OPERATION AND MAINTENANCE COSTS BY INDIVIDUAL SWM PROGRAM

Jurisdiction/ Agency/ Business	Number of Ponds Maintained	Total Area Maintained (Acres)	Size Range of Maintained Area (Acres)	Average Maintained Area (Acres)	Total Annual Program Cost (Dollars)[a]	Average Annual Maintenance Cost Per Pond (Dollars)	Average Annual Cost Per Maintained Acre (Dollars)
Dept. of Parks and Recreation City of Rockville Maryland	30	45	1-2	1.5	7,254	242	160
Parks Dept. Montgomery County Maryland-National Capital Parks and Planning Commission	40	45[b]	0.25-4.0[b]	1.1	25,788[d]	645	573
Magruder Constracting Corp. Rockville, Maryland	3	2.25	N/A	0.75	1,436	479	637
Dept. of Engineering City of Sterling Heights, MI	23	69	2-10	3.0	20,692[e]	900	299
Dept. of Public Works City of Troy, Michigan	58	78	0.2-6.6	1.3	70,755[f]	1,220	909
Waterworks, Waste & Disposal Dept. City of Winnepeg, Canada	44	440[c]	N/A	10.0	68,519[g]	1,557	156
TOTAL	198	679.25	-	-	194,444	-	-
AVERAGE	-	-	-	3.4	-	982	286

Notes:

N/A - Not available.
 - Not calculated.

[a] Program costs adjusted to common regional base using Engineering News Record, Baltimore Common Labor Index.

[b] Maintained areas calculated by COG and verified by M-NCPPC officials.

[c] Maintained area calculated by COG on bases of two times the pond 10-year surface elevation area.

[d] Does not include $20,000 reported for sediment removal operations.

[e] Does not include $30,000 reported for pond dewatering costs, and $6,400 for part of the Sterling Heights inspection program.

[f] Does not include $3,042 reported for electricity costs and $2,869 for equipment repairs.

[g] Does not include $14,000 reported for electricity costs for pond lighting.

Table 8

COMPARISON OF REPORTED LOCAL (METROPOLITAN WASHINGTON) AND NON-LOCAL SWM POND OPERATION & MAINTENANCE PROGRAM COSTS

	Jurisdiction/ Agency/ Business	Number of Ponds Maintained	Total Area Maintained (Acres)	Size Range of Maintained Area (Acres)	Average Maintained Area (Acres)	Total Annual Program Cost (Dec. 1980 Dollars)[a]	Avg. Annual Maintenance Cost Per Pond ($)[a]	Avg. Annual Cost Per Maintained Acre ($)[a]
Local Metropolitan Washington	Dept. of Parks & Recreation City of Rockville Maryland	30	45	1-2	1.5	7,254	242	160
	Parks Department Montgomery County M-NCPPC	40	45[b]	0.25-4[b]	1.1	25,788	645	573
	Magruder Association (Contractor) Rockville, Maryland	3	2.25	N/A	0.75	1,436	479	637
	LOCAL TOTALS	73	92.25	0.25-4	-	34,478	-	-
	LOCAL AVERAGES	-	-	-	1.26	-	$472	$374
Non-Local	Dept. of Eng. City of Sterling Hts, Michigan	23	69	2-10	3.0	20,692	900	299
	Dept. of Public Works City of Troy Michigan	58	78	0.2-6.6	1.3	70,755	1,220	909
	Waterworks, Waste & Disposal Department City of Winnepeg, Canada	44	440[c]	N/A	10.0	68,519	1,557	156
	NON-LOCAL TOTALS	125	587	0.2-10	-	159,966	-	-
	NON-LOCAL AVERAGES	-	-	-	4.70	-	$1,280	$273

Notes:

N/A - Not Available
[a] Program costs adjusted according to Engineering News Record, Dec. 1980 Baltimore Common Labor Index.
[b] Maintained areas calculated by COG and verified by M-NCPPC officials.
[c] Maintained area calculated by COG on basis of two times the pond 10-year surface elevation area.

Upon review of the three survey responses which itemized costs by maintenance category, it appears that routine site inspections, grass maintenance and minor debris removal account for most of the yearly O&M expenditure.

DEVELOPING O&M COST PROJECTIONS

As previously noted, the most common approach currently used for projecting annual O&M costs for SWM ponds is to calculate them as a percentage of construction costs. For single purpose detention/retention basins, SCS (1977) and NVPDC (1980) suggested that 5 percent of pond construction costs would suffice as a rough approximation of expected annual O&M costs, including periodic sediment removal. Others suggest a higher value (Monroe County, NY applies 12 percent to O&M); whereas in larger flood control projects with drainage areas of 1 to 20 square miles, utilization of 1/2 percent of project construction is suggested (SCS, 1977).

The O&M cost values of $286/maintained acre and $982/pond discussed in the preceding section (see also Table 7) were related to a representive sampling of 16 of the 31 ponds identified in Chapter I of this report to see how these O&M estimates compared with estimated pond construction costs. Maintained area sizes of the 16 ponds ranged from 0.60 to 3.5 acres. At $286 per maintained acre, O&M (exclusive of sediment removal) was seen to represent about 1.3 percent of the average construction costs of the 16 ponds. On a cost per structure basis, the $982 per pond estimate was seen to represent about 2.8 percent of average pond construction costs.

In view of these findings, a value of 2 to 3 percent of estimated pond construction costs was felt to a acceptable approximation of O&M costs, exclusive of sediment removal. The additional costs predicted for sediment removal operations are described below.

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[13] As shown, reported costs were adjusted to December 1980 dollars using the Baltimore Common Labor Index, Engineering News Record, in order to maintain comparable costs. Some reported costs were not included in the present O&M cost calculation if they pertained to sediment removal, dewatering, electrical use (pond lighting) or other tasks not felt to be directly comparable to Washington area circumstances.

SEDIMENT REMOVAL AND DISPOSAL

Documentation is extremely limited concerning the nature, magnitude, and costs of periodic sediment removal operations required for on-site SWM ponds draining stabilized, developed areas. This is due to the relative newness of the SWM programs in effect locally and the relatively insignificant loadings of sediment associated with runoff from stabilized urban and suburban areas (0.12-0.33 tons/ac/yr), as compared to loadings of 50 to 60 tons/ac/yr typical of uncontrolled construction site runoff found in the Washington region (NVPDC,1980). The principal factor influencing the scheduling of sediment removal, however, would be the sediment accumulation or pond storage depletion rates observed at a particular pond site through periodic site inspection. In this regard, NVPDC (1980) suggested that traditional SWM detention basins serving stabilized urban and suburban area and achieving approximately 50% sediment trap efficiency would exhibit storage depletion rates ranging from 1.4 to 3.9 cu ft/year/acre of drainage. Wet ponds and modified detention basin BMPs with "moderate to considerable drawdown" were estimated to achieve greater sediment trap efficiencies. For planning purposes, NVPDC assumed a 100 percent sediment trap efficiency for these structures,[14] such that their storage depletion rate were conservatively estimated at 2.8 to 7.8 cu ft/year/acre of drainage, or twice the rate for traditional peak shaving structures. NVPDC made further allowances for additional accumulation of sediment and non-degradable debris at high detention BMPs, suggesting an annual peak shaving storage depletion rate of 1 percent per year at these structures.

Sediment removal operations would presumably have to be initiated when accumulations began to reduce a pond's flooding/erosion control storage by an appreciable amount below design levels. In this regard, NVPDC suggested a clean-out cycle intended to maintain a pond's storm-related storage at no less than 95 percent of design value. APWA (1981) also noted instances where sediment removal should be initiated to maintain pond appearance and reduce nuisance plant growth. Recommended clean-out cycles could thus range anywhere from once every 5 years to once every 20 years, depending on site conditions, land use, soil type, topography, size of drainage area, weather conditions, and applicable SWM program goals.

Pond size or design has also been noted as a key factor affecting clean-out intervals. For example, a pond designed with storage in excess of SWM storage requirements would have additional storage available for sediment accumulation and hence require less frequent clean-out. Similarly, wet ponds have devoted considerable amount of their total storage volume to the permanent pool area, which from a purely theoretical standpoint, is available for sediment accumulation without encroaching on the structure's peak shaving storage.

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[14] Washington area 208 and NURP-sponsored studies suggest a sediment trap efficiency for wet ponds ranging from 40 to 90 percent.

Nature of Clean-Out Operations

Available guidance in the literature on the manpower and equipment requirements of sediment removal stems from field studies of sediment catch basins and detention/retention basins serving both as sediment traps and SWM structures in areas undergoing construction (Maryland Water Resources Administration, 1974; U.S. EPA, 1973). For dry ponds, these suggest utilization of a conventional front end loader and dump trucks. Wet pond excavation (with or without prior pond dewatering) would be carried out by conventional dragline with scraper bucket, or in the case of wider ponds which exceed the typical reach of a dragline, a modified dragline arrangement in which a crane-operated scraper bucket is attached to a cable secured on the opposite side of the pond (Figure 7). The general practice appears to involve either on-site grading and restabilization of pond sediments or hauling to a nearby disposal area.

Accumulated material is generally not considered suitable for re-use or re-sale as fill material, due to its high clay content and the odd assortment of debris it contains. Recent NURP studies suggest, however, no significant problems in terms of sediment contamination which would pose environmental hazards in disposal. A limited scan of local SWM pond sludges and bottom sediments detected few organic and inorganic chemicals.[15] Nickel, zinc, lead, and certain phenols were the inorganic substances detected, but were measured at fairly low level concentrations.

Projecting Sediment Removal Costs

It is difficult to confidently project sediment removal/disposal costs that would be applicable to all ponds and clean-out operations, due to the variability between specific pond sites and upstream drainage conditions. Recent data and field experience in the Washington region to date does, however, seem to indicate that relatively low accumulation rates have occured at most of the SWM ponds constructed in the region. Few sediment removal operations have yet been conducted either in response to perceived sedimentation problems or in response to complaints by adjacent residents.

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[15] "Final Report, Priority Pollutant Analysis," (Washington D.C. NURP Project), JTC Environmental Consultants, Inc., Sept. 30, 1982.

Clean-out operations[16] at the Stedwick dry pond NURP monitoring site in Montgomery County during August, 1982 provided an opportunity for COG staff to observe actual sediment accumulations which occured at a modified detention pond. Through installation of a perforated riser, this facility operated to achieve extended runoff detention periods on the order of 6 to 9 hours. Approximately 6 cubic yards of sediment which accumulated over the 18-month monitoring period (4 cubic yards/yr) were removed from the 145,490 cubic ft pond by the Montgomery County Department of Transportation (DOT). The pond drains a 34-acre medium density single family development.

Sediment accumulation rates observed at Stedwick (3.2 cu ft/yr per acre) were generally consistent with the relatively low sediment accumulation rates expected to occur in ponds serving a stabilized, medium density single family development. This field experience would appear to suggest that NVPDC's guidelines for annual sediment and debris accumulations at a storage depletion rate of 1.0 percent of flooding/erosion control storage per year for BMP detention basins may have been overly conservative for scheduling of clean-out operations. Use of the lower depletion rate estimates of 1.4 to 3.9 cu ft/yr per acre of drainage for single-purpose detention ponds, and depletion rate ranges of 2.8 to 7.8 cu ft/yr/drainage area for wet ponds and detention basins that have been modified to achieve detention periods up to 24 hours would appear to be more in-line with field observations to date.

Using these assumptions, accumulation rates for a theoretical single-purpose dry pond serving a 20-acre stabilized site could be expected to range from 270 to 780 cu feet (10-29 cubic yards at 27 cu yd/cu ft) over a 10-year period, depending on land use and pervious conditions in the drainage area; and 540-1566 cu ft (20-58 cubic yards) over ten years for a wet pond serving the same drainage. These lower storage depletion assumptions would, of course, not hold in instances where a portion of the pond's drainage area was still undergoing construction, such that the pond was serving as both a sediment catch basin and SWM structure. In such cases, pond clean-out may be required on a more frequent basis.[17]

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[16] A special clean-out was initiated at the Stedwick site to fulfill agreements that the pond site would be returned to pre- monitoring condition following the completion of NURP monitoring.

[17] This appears to have been the case with one recent wet pond clean-out operation at the Olney-Mills wet pond in Montgomery County. Approximately 1750 cu yd of sediment was removed from the pond in 1980 by the Maryland-National Park & Planning Commission after a 7 year period. The pond's 490 acre drainage area is still undergoing construction. Influent stream channel conditions are also characterized as highly erodable.

Estimated Unit Costs

The costs of sediment removal operations appears to vary considerably on a per cubic yard basis according to the complexity of the site, amount of material to be excavated, and availability of a means of disposal in proximity to the pond site. Even a small project, involving small quantities of sediment removal, can entail a considerable cost due to the expense of mobilizing crews and heavy equipment for a day or a fraction of a day. Project costs (exclusive of administration and contingencies) for the Montgomery County DOT clean-out of the Stedwick dry pond totaled approximately $260.[18] This could be considered as representing the low end of costs required for a small dry pond sediment removal operation. If the 18-month sediment accumulations were extended over a hypothetical 10-year period, resulting removal rates would amount to approximately $6.50/cubic yard. These costs include reseeding of disturbed area and hauling of material to an DOT storage yard for temporary stockpiling.

With regard to guidance on larger projects, cost estimates developed by Maryland WRA (1974) amounted to approximately $3.80 per cubic yard to remove approximately 2,000 cubic yards of sediment from a 610,200 cu ft wet pond in Columbia, Maryland, which over a two-year period (1970-1972) had served as a primary sediment trap and SWM retention pond for its upstream drainage. The $7,665 estimate for the operation pertained to excavation using a conventional dragline with 1-1/2 cubic yard scaper bucket to removal material close to shore (within 60 feet from the crane), switching to a long reach arrangement (Fig. 7) to remove material greater distances away. Sediments were scooped into a dry forebay area, then loaded by backhoe onto dump trucks and trucked to a disposal area 1-1/2 miles away.

WRA estimated that site restoration of disrupted areas could add an additional 18 percent to the sediment removal operation. This would increase original WRA job costs to $9,045 or $4.50 per cubic yard. If adjusted for inflation to December 1980 dollars, total job cost estimates would increase to roughly $17,200 or $8.60 per cubic yard removed (Engineering News Record, Construction Cost Index, Baltimore, Md). WRA cost projections for a larger sediment removal project (6,000 cubic yards) assumed that these costs would decrease somewhat, to approximately $2.20/cu yd (site restoration included), apparently due to the economies of a larger scale operation. These costs equal roughly $4/cu yd in December 1980 dollars (ENR Index).

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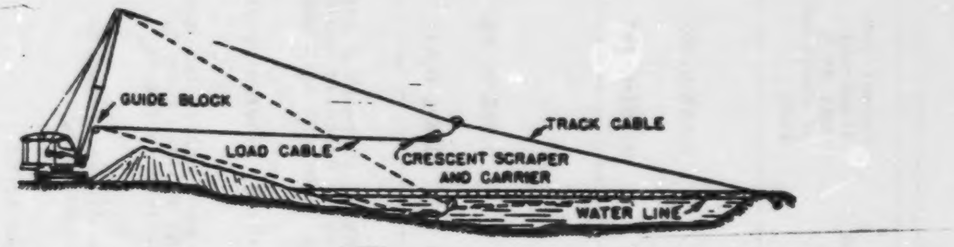
[18] Correspondence, Montgomery County Department of Transportation, Division of Transportation Engineering, July 16, 1982; August 20, 1982.



Source: Md. WRA

Figure 7
CRANE OPERATED DRAGLINE SCRAPER, TYPICAL ARRANGEMENT

This information, combined with discussions with local SWM officials, suggest a cost range of $5 to $8/cu yd for dry pond excavation, and $8 to $10/cu yd for wet pond excavation. Employing these estimates and the post-development storage depletion rates discussed above, it was felt that clean-out operations of a pond structure serving drainage acres less than 30 acres, scheduled once every ten years to maintain pond appearance and storage at design levels, could be reasonably estimated at $500 for a dry pond and $1,000 for a wet pond. Calculated on a annual basis (Table 9), the clean-out operations are seen to represent 0.2 percent to 0.75 percent of the construction cost of a dry or wet pond draining a 20-acre watershed.

With an allowance of 25 percent to cover administration, profit and overhead (where applicable), and contingencies, a value of 1 percent of construction costs was assumed to suffice for projecting costs of clean-out operations for both wet and dry ponds in drainage areas of less than 30 acres. This estimate assumes that the project will be able to dispose of sediments at or near the pond site. If fees are incurred for disposal of material at a land fill or rubble fill, estimated project costs could as much as double. Thus, in instances where off-site hauling distances are sizable and disposal charges are expected, an allowance of 2 percent of pond construction costs may be appropriately conservative.

As indicated in Table 9, this 1 to 2 percent projection also holds true for ponds serving 100 acre drainage areas.

Table 9

ESTIMATED SEDIMENT REMOVAL COSTS COMPARED TO POND CONSTRUCTION COST

10 Year Clean-Out Cycle

DRY POND	Storage Volume (cu ft)[a]	Estimated Base Construction Cost	Estimated Clean-out Cost[d]	Annualized Clean-out Cost (10 yr)	Annualized Clean-out Cost as % of Construction
20-Acre Drainage Area (18% to 90% Impervious)[b]	14,500-79,860	\$10,300-\$24,500	\$ 500[c]	\$ 50	0.48%-0.20%
100-Acre Drainage Area (18% to 90% Impervious)[b]	72,600-326,700	\$23,300-\$50,200	\$600-\$900	\$60-\$90	0.25%-0.18%
WET POND					
20-Acre Drainage Area (18% to 90% Impervious)[b]	29,200-159,720	\$14,600-\$34,900	\$1,000[c]	\$ 100	0.68%-0.28%
100-Acre Drainage Area (18% to 90% Impervious)[b]	145,200-653,400	\$33,200-\$71,500	\$2,300-\$2,900	\$230-\$290	0.69%-0.41%

[a] Assumes Fairfax County 10-year design storm criteria. Wet pond storage assumes for illustrative purposes a permanent pool volume equal to the required peak shaving storage volume. Montgomery County 2-year design storm criteria would require somewhat higher peak shaving volumes. Cost percentages shown would in this case be somewhat lower due to higher construction costs.

[b] Presents the range of imperviousness likely to be associated with a given land use. Tables 11-13 provide additional detail on land use - % impervious relationships.

[c] Sediment removal cost estimates are based on assumptions of \$5 to \$8 per cubic yard for dry pond operations and \$8 to \$10 per cubic yard for wet pond operations. However, a value of \$500 is assumed to be the minimum cost for dry pond clean-out operations and \$1000 as the minimum for wet pond clean-out, because of minimum equipment mobilization costs.

[d] Assumes on-site disposal of pond sediments or low cost disposal at nearby rubble fill. Long distance trucking and disposal at a rubble fill or land fills (including dumping fee) can increase total clean-out costs considerably, in some instances, doubling the per cubic yard costs shown here.

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Wet pond maintenance costs may be somewhat less than projected here, because the considerable volume of dead storage available for sediment accumulation may reduce the required frequency of sediment removal operations from every 10 years to something on the order of once every 20 years. The possibility of reduced maintenance requirements may weigh in favor of wet pond designs with greater permanent pool volumes.

CONCLUSIONS

Cost projections have been derived from the total O&M program costs reported by a number of organizations based on actual field experience and costs incurred in maintaining wet and dry pond structures in recent years. Taken as a whole, these programs covered a wide range of maintenance responsibilities and would appear to provide a fairly realistic approximation of the magnitude of costs likely to be incurred by pond maintenance programs. Annual O&M costs, with the exception of sediment removal, were seen to represent approximately 2 to 3 percent of average pond construction costs. Sediment removal operations, when considered on a 10-year clean-out cycle, are projected at 1 to 2 percent of base pond construction costs (see Chapter I) on an annual basis. Combining all annual maintenance costs, a rule of thumb of 3 to 5 percent of estimated base pond construction costs is proposed as an appropriate planning level approach to projecting or budgeting annual O&M costs.

Methods of projecting these annual costs will undoubtedly improve in future years as local programs gain experience in pond maintenance and begin to keep more detailed records on annual O&M expenditures and man-hour requirements.

CHAPTER III

INCREMENTAL COSTS ASSOCIATED WITH MODIFIED SWM PONDS OR BMPs

NVPDC (1980) suggested several design modifications to traditional peak-shaving SWM retention/detention basins which would increase the detention times of these structures, to improve their solids settling and pollutant removal capability while maintaining the flooding/erosion control objectives associated with the traditional peak shaving design. Such modifications were intended to convert SWM structures into a multi-purpose "Best Management Practice" (BMP) pollution control devices. Recommended modifications included increasing storage volumes by 15 to 25 percent to achieve a a Nonpoint Source Pollution (NPS) Management storage volume. The use of perforated risers and/or sub-surface drains in pond design was also suggested to increase the detention period in dry ponds to up to 24 hours. In addition, pond length to width ratios on the order of 3:1 were recommended for both wet and dry pond construction designs to maximize the distance available between pond inflow and outflow and thereby promote improved solids settling.

In terms of additional design requirements for wet ponds, recent analyses of measured pond pollutant removal efficiencies conducted for COG by NVPDC under the Washington Area NURP project indicate that traditionally designed wet or permanent pool SWM ponds achieve a higher degree of pollutant removal than was originally anticipated and, in effect, act as effective BMPS without further modification. In light of these findings, the evaluation contained in this chapter is confined to an assessment additional construction costs associated with modified detention (dry pond) design. The incremental O&M costs which may result due to improved trap efficiencies of modified dry ponds are also considered.

MODIFIED DRY POND CONSTRUCTION

Design plans for each of nine representative dry ponds utilized in the construction cost analysis described in Chapter I were redesigned by COG staff to incorporate new or revised unit components required to achieve the BMP designs and recommended release rates, including allowances for increased storage volume and different pipe sizings. Modified design and unit component assumptions considered in this analysis included:

- Total pond storage volume (to the crest of the emergency spillway) was increased by 19 percent achieve additional

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NPS storage. This storage increase was based on the assumption that a portion of the NPS component of a pond could be used to satisfy a portion of the flooding/erosion control requirement during the initial stages of a design storm. Costs to achieve this additional storage volume were associated with additional excavation.

- The redesigned ponds were equipped with a non-perforated riser, serving as the principal spillway, and an anti-vortex hood/trash rack. In some ponds, use of the riser eliminated the need for endwalls previously located at the pond outlet.

- Subsurface drains were utilized to maintain low NPS release rates. Drains were selected as opposed to perforated risers because they are estimated to have the advantage over riser outlet controls of removing both suspended and dissolved pollutant loadings through natural processes (e.g., filtration, adsorption, biological decomposition) in the 2-3 feet of soil between the bottom of the detention basin and the top of the drain.

Unit costs as reported by the 12 respondants identified in Chapter I were then applied to each of the nine modified pond designs to develop a series of new cost estimates for the ponds. Table 10 compares the estimated average construction costs of the ponds prior to design modification with the estimated average cost of building each pond as a multi-purpose BMP facility. Much of the variation in the incremental cost of BMP construction can be attributed to the variability of site conditions and construction components of the ponds prior to modification. As a general statement, construction of a detention pond BMP could be said to involve an incremental cost increase on the order of 10 to 12 percent over single purpose detention basin construction.

Table 10

INCREMENTAL COSTS OF MODIFIED DETENTION POND BMPs

	ESTIMATED CONSTRUCTION COST ($)		INCREMENTAL COST INCREASE
POND	Peak-Shaving Facility	BMP	(%)
1	$23,044	$25,493	11
2	27,965	29,336	5
3	12,922	15,609	21
4	34,589	38,152	10
5	6,311	8,062	28
6	5,194	6,427	24
7	38,973	39,844	2
8	53,316	54,305	6
9	22,291	23,056	3
Mean % Increase			12.2
Median % Increase			10.0

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Incremental O&M Costs

The O&M cost projections presented in Chapter II represent costs incurred by SWM programs observing a fairly extensive range of pond maintenance functions, including in many cases, frequent site inspections, removal of floatables and trash, replacement of riprap, and periodic sediment removal based on fairly conservative sediment accumulation rates. Dry pond BMP modifications are not expected to require a greater degree of maintenance than that required by single purpose detention/retention facilities. Utilization of an O&M projection based on the 3 to 5 percent of base construction cost approach discussed in Chapter II should hence be sufficient to cover any BMP-related O&M. Indeed, because of the increased base construction costs of BMP detention basins, the resulting O&M allowance would be about 10 to 12 percent higher than for an unmodified SWM pond, thus falling in the high range of O&M cost projections.

CHAPTER IV

EVALUATION OF TOTAL PROJECT COSTS

This chapter integrates the pond construction and maintenance cost projections presented in Chapters I and II of this report to identify total annual project costs that may be anticipated for a pond facility over a twenty year planning period. It also relates these costs to typical residential and commercial development projects on a cost per dwelling unit or cost per acre basis. The chapter includes further comments on public and private SWM financing, and identifies considerations which might influence the financial and management option selected.

ANNUALIZED COST PICTURE

Tables 11-13 present the base construction, total construction, and maintenance costs for ponds serving hypothetical 20-acre and 100-acre developments covering a range of land uses. Estimated peak-shaving storage requirements for each land use are shown according to the governing design criteria observed in Montgomery and Fairfax Counties. Total construction costs and annual O&M costs (assumed at 5% of base construction) have also been amortized over 20-years at an 8 percent discount rate to illustrate a schedule of payments over a typical 20-year planning period.[19]

. Taking as an example a dry detention basin (26,862 cu ft) capturing runoff from a 20-acre medium density single family (4 DU/Acre, 80 DU/20 Acre) sub-division in Fairfax, County (Table 11), sample calculations for total annual amortized project costs can be derived, where:

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[19] The 8 percent discount rate is slightly higher than the 7 5/8 rate currently recommended by U.S.EPA for evaluating the costs of water resource projects in fiscal year 1982. Selection of a 20-year planning period does not imply a 20 year pond life. A 50-year pond life for a well maintained pond is probably not unrealistic.

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(1) Total Construction Cost = $(1.25)(77.4)(26,862)^{0.51}$
(Estimated Base Construction
plus a 25% allowance for = \$17,560
planning, design, and
administration)

(2) Annual O&M Costs = $(0.05)(77.4)(26,862)^{0.51}$
(5% of Base Construction) = (0.05)(\$14,048)
= \$702

(3) Total Present Worth of Project
(20 yrs. at 8 percent) = \$17,560 + \$702(9.818)
= \$17,560 + \$6,892
= \$24,452

(4) Equivalent Annual Payment = \$24,492 (0.1018)
(Total Cons. and O&M) = \$2,489

(5) Equivalent Annual Payment
per Dwelling Unit = \$2,489/80 DU = \$31

There are several observations which can be drawn from the tables. For example, costs per dwelling unit decrease as one moves from a large lot single family situation to more intensive residential developments. This is due to fact that project costs are spread out over more dwelling units. At the same time, peak shaving storage requirements to handle the additional units have not increased at the same rate.

Long term financing, amortized here at 8% over 20 years, has as one might expect a dramatic escalating effect on annual total program costs. Annual amortized costs per dwelling unit can be expected to be significantly higher than for projects financed with cash-on-hand. The tables also show the considerable cost advantages of building larger ponds which serve a larger drainage area or greater portion of a development. Costs per dwelling unit of ponds serving a 100-acre development are on the order of 50 percent less than ponds costs associated with 20-acre drainage areas.

Lastly, the more stringent peak shaving requirements in Montgomery County result in slightly higher project costs per dwelling unit as compared to Fairfax County. For example, amortized annual project costs (dry pond) for a 20-acre townhouse development in Fairfax County (Table 11) are \$9/D.U. versus \$12/D.U. in Montgomery County (Table 12).

Table 13 indicates the total pond volume and costs associated with both dry and wet ponds.

Table 11

PROJECTED CONSTRUCTION AND MAINTENANCE COSTS OF SWM DRY DETENTION PONDS
20 and 100 Acre Developments

Fairfax County 10-Year Design Storm Criteria[a]

LAND USE (20 Acre Development)	PEAK SHAVING STORAGE	ESTIMATED BASE CONSTRUCTION COST ($)	ESTIMATED TOTAL CONSTRUCTION COST ($) WITH 25% FOR PLANNING, DESIGN, ADMIN.	TOTAL CONSTRUCTION COST ($) PER D.U.	ESTIMATED ANNUAL O&M COST ($)[b]	ANNUAL O&M COST($) PER D.U.[d]	TOTAL ANNUAL CONSTRUCTION AND O&M ($) (20 Yrs. at 8%)	TOTAL ANNUAL CONSTRUCTION AND O&M ($) PER D.U.[d] (20 Years at 8%)	TOTAL ANNUAL CONSTRUCTION AND O&M ($) (20 Year Straight Line)	TOTAL ANNUAL CONSTRUCTION AND O&M ($) PER D.U.[d] (20 Year Straight Line)
Large Lot Single Family 1 D.U./Acre 12% Impervious	14,520	10,265	12,831	642	513	26	1,919	91	1,155	58
Medium Density Single Family 4 D.U./Acre 25% Impervious	26,862	14,048	17,560	220	702	9	2,489	31	1,600	20
Townhouse/Garden Apartment 10 D.U./Acre 40% Impervious	33,396	15,697	19,621	88	785	4	2,782	14	1,766	9
High-Rise Residential 30 D.U./Acre 70% Impervious	59,532	21,080	26,350	44	1,054	2	3,736	6	2,372	4
Commercial N/A 90% Impervious	79,860	24,487	30,609	1,530[c]	1,224	61[c]	4,339	217[c]	2,754[c]	138[c]
LAND USE (100 Acre Development)										
Large Lot Single Family 1 D.U./Acre 12% Impervious	72,600	23,325	29,156	292	1,166	12	4,133	41	2,624	26
Medium Density Single Family 4 D.U./Acre 25% Impervious	134,310	31,921	39,901	100	1,596	4	5,657	14	3,591	9
Townhouse/Garden Apartment 10 D.U./Acre 40% Impervious	166,980	35,670	44,587	45	1,784	2	6,322	6	4,013	4
High-Rise Residential 30 D.U./Acre 70% Impervious	254,100	44,187	55,234	18	2,209	1	7,831	3	4,971	2
Commercial N/A 90 Impervious	326,700	50,229	62,787	628[c]	2,511[c]	25[c]	8,901	89[c]	5,650[c]	57[c]

Notes:

N/A - Not Applicable.

[a] Fairfax County peak shaving detention basin design requires maintenance of post development peak flow from a 10-year Fairfax County design criteria storm at a predevelopment level of approx. 0.92 in/hr.

[b] Based on 5% of Estimated Construction Costs.

[c] Costs per acre.

[d] Rounded to nearest whole dollar.

Table 12

PROJECTED CONSTRUCTION AND MAINTENANCE COSTS OF SWM DRY DETENTION PONDS
20 and 100 Acre Developments

Montgomery County 2-Year Design Storm Criteria[a]

LAND USE (20 Acre Development)	PEAK SHAVING STORAGE	ESTIMATED BASE CONSTRUCTION COST ($)	ESTIMATED TOTAL CONSTRUCTION COST ($) WITH 25% PLANNING, DESIGN, ADMIN.	TOTAL CONSTRUCTION COST ($) PER D.U.	ESTIMATED ANNUAL O&M COST ($)[b]	ANNUAL O&M COST ($)[d] PER D.U.	TOTAL ANNUAL CONSTRUCTION AND O&M ($) (20 Years at 8%)	TOTAL ANNUAL CONSTRUCTION AND O&M ($) PER D.U.[d] (20 Years at 8%)	TOTAL ANNUAL CONSTRUCTION AND O&M ($) (20 Year Straight Line)	TOTAL ANNUAL CONSTRUCTION AND O&M ($) PER D.U.[d] (20 Year Straight Line)
Large Lot Single Family 1 D.U./Acre 12% Impervious	10,000	8,487	10,609	530	424	21	1,504	75	954	48
Medium Density Single Family 4 D.U./Acre 25% Impervious	32,000	15,354	19,199	240	768	9	2,722	34	1,728	22
Townhouse/Garden Apartment 10 D.U./Acre 40% Impervious	56,000	20,432	25,540	128	1,022	5	3,621	18	2,299	12
High-Rise Residential 30 D.U./Acre 70% Impervious	105,000	28,154	35,193	59	1,408	2	4,990	8	3,168	5
Commercial N/A 90% Impervious	140,000	32,604	40,755	2,204[c]	1,630	82[c]	5,778	289[c]	3,668	183[c]
LAND USE (100 Acre Development)										
Large Lot Single Family 1 D.U./Acre 12% Impervious	62,500	21,609	27,012	270	1,080	11	3,829	38	2,431	24
Medium Density Single Family 4 D.U./Acre 25% Impervious	100,000	37,062	46,238	116	1,853	5	6,560	16	4,165	10
Townhouse/Garden Apartment 10 D.U./Acre 40% Impervious	310,000	48,903	61,129	61	2,445	2	8,667	9	5,501	6
High-Rise Residential 30 D.U./Acre 70% Impervious	550,000	65,513	81,891	27	3,276	1	11,611	4	7,371	2
Commercial N/A 90% Impervious	750,000	76,740	95,925	959[c]	3,837	38[c]	13,600	136[c]	8,633	86[c]

Notes:

N/A - Not applicable

[a] Montgomery County Peak shaving detention basin design requires maintenance of post-development peak flow from a 2-year Montgomery County design criteria storm at predevelopment levels of approx. 0.6 to 0.8 in/hour.

[b] Based on 5% of Estimated Construction Costs.

[c] Costs per acre.

[d] Rounded to nearest whole dollar.

Table 13
SUMMARY COST PROJECTIONS: 100 ACRE DEVELOPMENT
Dry Ponds and Wet Ponds*

	Peak Shaving Storage[a]	Total Construction Cost Per D.U. ($)[b]	Annual O&M Per D.U. ($)[c]	Annualized Total Project Costs($) Per D.U. (20 yrs. at 8%)[d]	Annualized Total Project Costs ($) Per D.U. (20 Years, Straight Line)[d]
FAIRFAX COUNTY					
Large Lot Single Family 1 D.U./Acre 12% Impervious	72,600 (254,100)	292 (552)	16 (22)	41 (78)	26 (50)
Medium Density Single Family 4 D.U./Acre 25% Impervious	134,310 (315,810)	100 (154)	4 (6)	14 (22)	9 (14)
Townhouse/Garden Apartment 10 D.U./Acre 40% Impervious	166,980 (348,480)	45 (65)	2 (3)	6 (9)	4 (6)
High-Rise Residential 30 D.U./Acre 70% Impervious	254,100 (435,600)	18 (24)	1 (1)	3 (3)	2 (2)
Commercial N/A 90% Impervious	326,700 (508,200)	628[e] (787)[e]	25[e] (31)[e]	89[e] (112)[e]	57[e] (71)[e]
MONTGOMERY COUNTY					
Large Lot Single Family 1 D.U./Acre 12% Impervious	62,500 (224,000)	270 (541)	11 (22)	38 (77)	24 (49)
Medium Density Single Family 4 D.U./Acre 25% Impervious	180,000 (361,500)	116 (165)	5 (7)	16 (23)	10 (15)
Townhouse/Garden Apartment 10 D.U./Acre 40% Impervious	310,000 (491,500)	61 (77)	2 (3)	9 (11)	6 (7)
High-Rise Residential 30 D.U./Acre 70% Impervious	555,000 (736,500)	27 (32)	1 (1)	4 (5)	2 (3)
Commercial N/A 90% Impervious	750,000 (931,500)	959[e] (1,071)[e]	38[e] (43)[e]	136[e] (152)[e]	86[e] (96)[e]

Notes:

*Cost projections and sizing for wet ponds shown in parenthesis ( ). Wet pond storage includes peak shaving storage plus a permanent pool volume equal to one half inch runoff/drainage area.

[a] Peak shaving storage based on Fairfax County 10-Year storm design criteria and Montgomery County 2-Year storm design criteria.

[b] Includes 25% allowance for planning, design and administration.

[c] Based on 5% of Estimated Base Construction Cost.

[d] Accounts for both total construction (with 25% allowance) and O&M. Estimates rounded to nearest whole dollar.

[e] Costs per acre.

MWCOG, 6/83

Long Term Program Financing Considerations

The institution of stormwater management programs locally and across the country have posed a difficult series of questions regarding appropriate financing arrangements for pond structures and the most functional and equitable means for assigning responsibilities for their construction and upkeep. Washington area on-site SWM programs established in the last ten years generally have well-defined ordinances and maintenance agreements which assign responsibility for pond construction and maintenance to the developer in instances where implementation of on-site controls is considered by the regulating agency to be feasible and cost-effective.

In Maryland suburban jurisdictions, the recent trend seems to be towards increased public agency involvement, either through construction of public off-site SWM facilities financed through both public and private developer contributions, or cases where a public agency assumes responsibility for maintaining a private on-site facility. Local examples include the City of Rockville, Md., which now maintains approximately 27 privately constructed, on-site facilities, and the Washington Suburban Sanitary Commission, which in 1982 assumed maintenance responsibility for 25 privately built structures. Both Rockville and Montgomery County, Md. permit a waiver of all or part of a developer's on-site control requirements if a developer elects to contribute a pro-rata fee towards construction of a public off-site facility.

Current literature and comments made by SWM officials would seem to support this trend towards increased governmental responsibility in the implementation and administration of these programs, particularly in the area of pond maintenance. The most commonly encountered view is that it is doubtful that the degree of maintenance required to keep SWM ponds operating as designed would occur if the maintenance responsibility were completely left up to the individual property owner (often a homeowner's association). This is especially true if maintenance needs are not identified through regular public inspection. A recent report for the City of Albuquerque suggests that that pond maintenance by property owners is rarely adequate (APWA, 1981). Generally, a distinction is made between maintenance functions which a property owner or homeowner's association can or should be expected to perform. Homowners within a development in which a detention basin or permanent pond is built are typically considered to have the capability for "housekeeping" or aesthetic maintenance. This would include mowing and removal of trash or floatables. On the other hand, the point is made that it is impractical or unfair to expect private property owners to determine when structural repairs or sediment removal is needed, or to oversee a major structural repair or clean-out operation (APWA,1981; Dean, 1981). Thus current thinking appears to favor a greater public agency role in pond maintenance. At a minimum, this would involve public inspection and enforcement.

The Sterling Heights, Michigan Example

The on-site detention facility program instituted by Sterling Heights, Michigan provides one example of a management and financing approach for on-site control which relies on a mix of responsibilities assumed by both private and public sectors. There are approximately 55 separate retention/detention facilities located within the City at present, one-third of which are privately owned. Private facility maintenance is provided either by the property owner under a maintenance agreement with the City, or by the City based on receipt of a lump sum payment from the developer to cover maintenance over a 15 year period.

In the first instance of private maintenance, a written maintenance agreement is executed which provides that the property owner/manager will assume responsibilities for all maintenance, including mowing, trash removal, fence repair and sediment removal. When executing the maintenance agreement, private owners/managers are required to deposit a specified amount of money (approximately $4000/basin or $5 per week per basin for a 15 year period) in a special abandonment and maintenance fund. The fund is intended to defray the costs of regular site inspections conducted by the city over a 15-year period. In the event a proprietor fails to perform adequate maintenance, the City is empowered to perform corrective maintenance. The costs of any such remedial action taken by the city are then charged the proprietor. Provisions in the agreement convey easements and right-of-way to the city to have access to the property for inspection and maintenace purposes. The City assumes all maintenance costs and responsibilities after the expiration of the 15-year period.

Property owners also have the option of transferring maintenance responsibilities to the City. In this case, the property owner pays the City a lump sum of $10,000 - $30,000, depending on site circumstances, to cover maintenance over a 15 year period. The City then customarily contracts out the private pond maintenance to a private contractor through a bidding process. The City inspects both private and publicly owned pond facilities on a bi-weekly basis. Private pond owners are assessed $5 per inspection.

Alternative Public Finance Options

Table 14 indicates the methods of financing used by various public SWM programs around the country to fund capital as well as annual operation and maintenance costs of on-site and off-site facilities. Sterling Heights and a number of other programs have taken the approach that landowners contributing to stormwater runoff should pay for the cost of stormwater management service. Washington area programs have for the most part adopted the same principle, but at present also intend to utilize public funds drawn from general funds (Capital Improvements Program) or traditional sources such as ad-valorem taxes to fund construction of off-site facilities in developing or previously developed areas. This approach has attempted to strike a balance of funding sources between new development paying its "fair share" and the total tax base.

Other programs pay for public retention/detention facilities through user charges or stormwater utility fees collected from homeowners served by the overall storm drainage system. Fee schedules and user charge rates assessed individual property owners are generally calculated according to parcel size, percent imperviousness, and zoning category.

Some Recommended Elements of Public SWM Programs

A thorough discussion of the relative merits of various public finance options is beyond the scope of this report. However, the Sterling Heights example and other experiences reported in the literature suggest several important elements which should be incorporated into public programs:

1. The financing mechanism selected should make adequate allowance for total costs likely to be incurred by the SWM agency, including periodic operation and maintenance, over a specified planning period. Allowances should be made for increased administrative and engineering costs if the agency is assuming a greater oversight role which might include major corrective pond maintenance or new billing procedures.

Table 14

MECHANISMS EMPLOYED FOR FINANCING STORMWATER MANAGEMENT RETENTION/DETENTION FACILITIES

Municipality or Agency	Source of Capital for Construction	Source of Funds for Operation and Maintenance	Rates	Comments
Fairfax Co., Va. private facility	Property Owner/ Developer	Property Owner/ Developer	-	Bonds repaid through county general fund
public facility	Bonds and pro-rata developer contributions	County General Fund	None	
Howard Co., Md. private facility	Property Owner/ Developer	Property Owner/ Developer	-	Developer may request to contribute to county fund in lieu of on-site control.
public facility	Stormwater Management Fund; Developer contributions	General Fund	Based on storage required for on-site facility ($15,000/ac. ft)	
Montgomery Co., Md. private facility	Property Owner/ Developer	Property Owner/ Developer	-	Developer contributions based on waiver of on-site detention/retention requirement. Public maintenance of private on-site facilities under consideration; would be paid through either general funds or ad-valorem tax.
public facility	General obligation bonds; Developer contributions to Stormwater Management Participation Fund	Ad-valorem tax under consideration	Fee schedule charged developer based on average cost of providing on-site controls by zoning category assuming maximum % imperviousness allowed.	
Rockville, Md. private facility	Property Owner/ Developer	Property Owner/ Developer	-	Developer has option of paying fee for off-site pond construction in lieu of on-site control. City has accepted approximately 27 private on-site SWM structures for maintenance.
public facility	Stormwater Management Fund from general funds and developer contributions	Stormwater Management Fund; Developer contributions	on-site facility costs assuming maximum % imperviousness allowed by zoning category	
Austin, Texas private facility (subdivisions)	Property Owner/ Developer	Service fee for city maintenance	$80/lot for maintenance; $20/lot for monitoring	Commercial lot basins maintained by owner.

Table 14

MECHANISMS EMPLOYED FOR FINANCING STORMWATER MANAGEMENT RETENTION/DETENTION FACILITIES

Municipality or Agency	Source of Capital for Construction	Source of Funds for Operation and Maintenance	Rates	Comments
Denver (Colorado) Urban Drainage and Flood Control District	Annual user charge on improved property	Annual user charge on improved property	Rates of $0.37 - $1.17 multiplied by ratio group (ratio of impervious surface area of parcel to total parcel area). Minimum annual charge is $3.70/parcel.	Revenues estimated at $4.7 million annually, to be used for both capital needs and O&M.
Billings, Montana	Annual user service charge	Annual user service charge	$ per square ft./sq. meter rates based on zoning category	
Bellevue, Washington (Stormwatr utility within Dept. of Public Works	Monthly service charge	Monthly service charge	Rates per parcel based on parcel size and percent imperviousness ("Intensity of Development Classification".)	
Sterling Hgts., MI private	Property Owner/ Developer	Property Owner/ Developer	Private property owner assessed lump sum payment of $10,000-$30,000 for city O&M covering 15 years, plus $5/visit for city inspection of private facilities.	Private property owner may elect to have city maintain pond.
public	City-wide levy	Property Owner/ City-wide levy		

SOURCES: American Public Works Association, "Urban Stormwater Management: Special Report No. 47," 1981; Montgomery County Stormwater Management Project Financing Committee, Memorandum, April 25, 1979; Personal Communications.

2. Maintenance agreements between management agency and private landowners should clearly spell-out the responsibilities and liabilities assumed by private and public sectors. Legal obligations carried over to homeowners' associations assuming property property ownership should be carefully defined. Consideration should be given to the length of time a private property owner retains maintenance responsibility.

3. Public agencies should retain the option to maintain SWM ponds in the event pond maintenance is not considered adequate. Public easements to permit perpetual access to the facility should be secured for this purpose. Care should be taken in the design review process to ensure that pond designs provide access to outlet structures and maintain sufficient area (20-25 feet) around the pond free from obstructions which would prevent clean-out operations or routine maintenance.

4. Consideration should be given to implementing public site inspection programs.

5. Provisions should be developed to ensure reimbursement of costs incurred by the SWM agency for any remedial maintenance of a private facility.

6. Program objectives should be clearly defined to both property owners and affected publics to promote wider acceptance of any finance charges, ad-valorem taxes, or other funding mechanisms that might be required to sustain an effective program.

APPENDIX A

SAMPLE UNIT COST SURVEY FORM

COG SURVEY AND TRANSMITTAL LETTER
DISTRIBUTED TO WASHINGTON, D.C. AREA
STORMWATER MANAGEMENT, PUBLIC WORKS AND PLANNING AGENCIES
AND APPROXIMATELY 30 BUILDING AND ENGINEERING/CONSULTING FIRMS

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metropolitan washington
COUNCIL OF GOVERNMENTS
1875 Eye Street, N.W., Suite 200, Washington, D.C. 20006 223-6800

TRANSMITTAL LETTER

Dear

The Metropolitan Washington Council of Governments (COG) would like to request your assistance in the collection of certain cost information keyed to the Washington Metropolitan area.

During the next two (2) years, the COG Water Resources Planning Board (WRPB)* will be conducting intensive field studies to develop detailed pollutant removal efficiency and cost information on presently required stormwater management (SWM) structures and alternative "best management practices" (BMPs) that are currently available to remove pollutants entrained by and dissolved in urban storm runoff. These measures include such items as "wet" and "dry" ponds as well as infiltration structures of different designs. Recent research conducted by COG has determined that as much as half of all pollutants entering the Potomac River from the Metropolitan Washington area originate in urban runoff, with regional water supply reservoirs being similarly affected.

The COG study is being conducted under the auspices of the US EPA Nationwide Urban Runoff Program (NURP), with additional financial and technical support being provided by area local governments, the Northern Virginia Builders Association and the National Association of Home Builders. Information obtained under NURP is to be used both locally and nationally to evaluate the costs of alternative pollution control strategies that may be implemented to meet clean water goals. Within the Metropolitan Washington area, data collected will be used to assess the cost effectiveness of alternative control programs needed to protect area water quality. This assessment will be based upon evaluation of potential tradeoffs between various levels of wastewater treatment and urban runoff control within the region designed to reduce total pollutant loads discharged so that area waters are protected in the most cost-effective manner.

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*The COG Water Resources Planning Board serves as the designated regional water quality management planning agency for the Washington Metropolitan area as defined under PL-92-500, Section 208, as amended. Members of the WRPB include elected officials from local governments, the States of Maryland, Virginia, the District of Columbia (acting as a state), the Northern Virginia Planning District Commission and the Interstate Commission of the Potomac River Basin.

District of Columbia • Arlington County • Fairfax County • Loudoun County • Montgomery County • Prince George's County • Prince William County
Alexandria • Bowie • College Park • Fairfax City • Falls Church • Gaithersburg • Greenbelt • Rockville • Takoma Park

In order to provide a balanced assessment of the cost of urban runoff controls, we are soliciting cost estimates for the individual components that are used in the construction of stormwater runoff control measures. Attachment A to this letter contains a list of those individuals from whom we are requesting this information. We are asking that each respondent provide "in place unit costs"* for components typically used in the construction of storm drain and stormwater management systems presently required by many jurisdictions within the Metropolitan Washington area. "In place costs" provided should be those currently used by your organization to prepare or evaluate project construction cost estimates or bids. Since site conditions are often highly variable, the difficulties of assigning exact costs to a specific item are recognized. Therefore, it is requested that either average in place costs or a range of costs be provided.

COG staff will use the responses to this inquiry to compile a regional "Unit Cost List" that reflects construction costs of these components throughout the Washington area. The composite list will then be used as a guide to identify typical capital costs for both conventional stormwater management facilities and various types of BMPs. The resulting facility cost relationships will be provided to the region's local jurisdictions to assist them in identifying cost implications associated with the various runoff control requirements. Attachment B provides an example of how a preliminary Unit Cost List was applied to a specific detention pond to estimate its capital cost.

Thank you very much for your assistance. The WRPB remains committed to providing the Metropolitan Washington community with the kinds of detailed information it needs to make informed and cost-effective decisions concerning future area water quality management. The information you submit will help insure that data collected for these purposes is as complete as possible. Should you have any questions about any aspect of this project, please do not hesitate to contact me or George DeBuchananne of my staff at 223-6800, extension 454. Thank you again for your cooperation.

Sincerely,

Cameron Wiegand
Chief, Air and Water Programs
Department of Environmental Programs

Attachments

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*"In Place Unit Costs" are defined as the prices of individual components installed at a site. This would include, for example, the price of pipe FOB from the factory, transportation costs to the job site if needed, and other site preparation and installation costs.

NATIONAL ASSOCIATION OF HOME BUILDERS
NATIONAL HOUSING CENTER 15th AND M STREETS, N.W. WASHINGTON, D.C. 20005 (202) 452-0200

November 26, 1980

As a valuable member of the Suburban Maryland Home Builders Association and of the National Association of Home Builders, you have been identified as a possible resource for compiling stormwater management cost information.

One of the major tasks of NAHB's Clean Water Program has been to gather information on stormwater management practices. We are doing this because the U.S. Environmental Protection Agency is encouraging local governments to require certain management practices of developers to reduce pollution from urban stormwater runoff.

At present there is no definitive cost data that demonstrates which types of stormwater control practices are the most cost effective. To remedy this data deficiency and to determine which practices are the most cost effective response to water quality needs, I need your assistance.

NAHB has been working very closely with the Washington Council of Governments (COG) in their Nationwide Urban Runoff Program and the cost information compiled will shape the stormwater requirements imposed throughout the region. The building industry has the unique opportunity to provide direct input into this study and actual cost data will support our arguments on which stormwater management approaches are the most appropriate for our future subdivision designs.

Please take some time and read the attached information. Complete the stormwater management cost information sheet and send it to the Washington COG representative as soon as practical.

Your response is important to our national effort. Most importantly your response is critical to the future development of the Washington, D.C. Region.

If we do not have input from the building community which should have the most accurate cost information, then we will have to deal with cost data solely supplied by regulatory agencies. Your assistance would be greatly appreciated and if you should have any questions, please call me at (202) 452-0360 or George DeBuchananne, Washington COG at (202) 223-6800 x 454. Thanks.

Sincerely,

David E. Johnson

David E. Johnson, P.E.
Program Manager for Site Engineering
Technical Services Department

DEJ:dec

SURVEY FORM

"IN PLACE UNIT COSTS"*

LIST OF COMPONENTS USED IN CONSTRUCTION OF STORMWATER MANAGEMENT FACILITIES

ITEM	IN PLACE UNIT COSTS	UNIT OF MEASUREMENT
1. Common Excavation		Cubic Yard (c.y.)
2. Ditch Excavation		c.y.
3. Compacted Fill		c.y.
4. Clearing		per acre
5. Clear and Grubbing		per acre
6. Sodding		sq. yd. (s.y.)
7. Hydro Seeding		per acre
8. Seeding and Mulching		per acre
9. Gravel		
a. MSHA #2		per ton
b. MSHA #6 crusher run		per ton
10. Rip Rap		c.y.
11. Bituminous Curb		Linear Foot (L.f.)
12. Gabion		c.y.
13. Concrete Curb & Gutter		L.f.
14. Sub drains		
a. 6"		L.f.
b. 12"		L.f.
15. Standard Concrete Flume (6")		s.y.
16. WSSC Concrete Low Cradel Bedding		s.y.
17. Anti Seep Collars (Steel)		
a. for 12" pipe		each (ea.)
b. for 18" pipe		ea.
c. for 36" pipe		ea.
d. for 42" pipe		ea.
e. for 54" pipe		ea.

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*"In Place Unit Costs" are defined as the price of individual components installed at the site. This would include for example, the price of pipe FOB from the factory, transportation costs to the job site if needed, and other site preparation and installation costs.

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ITEM	IN PLACE UNIT COST:	UNIT OF MEASUREMENT
18. Riser Fabrication (BCCMP)		
a. for 18" Riser		ea.
b. for 36" Riser		ea.
c. for 42" Riser		ea.
d. for 60" Riser		ea.
19. "Concentric" Anti Vortex Device		
a. for 18" Riser		ea.
b. for 36" Riser		ea.
c. for 42" Riser		ea.
d. for 60" Riser		ea.
20. Reinforced Concrete Pipe*		
a. 15"		Per Linear Foot (L.f.)
b. 18"		L.f.
c. 21"		L.f.
d. 24"		L.f.
e. 27"		L.f.
f. 30"		L.f.
g. 36"		L.f.
h. 42"		L.f.
i. 48"		L.f.
j. 54"		L.f.
k. 60"		L.f.
l. 66"		L.f.
m. 72"		L.f.
21. Bituminous Coated Corrugated Metal Pipe (BCCMP)*		
a. 15"		L.f.
b. 18"		L.f.
c. 21"		L.f.
d. 24"		L.f.
e. 30"		L.f.
f. 36"		L.f.
g. 42"		L.f.
h. 48"		L.f.
i. 54"		L.f.

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*Pipes are assumed to be used as pond barrels. As such, do not include ditch excavation as part of emplacement cost, or please note depth at which installation is assumed. Please include cost of bedding, as per local requirement.

ITEM	IN PLACE UNIT COSTS	UNIT OF MEASUREMENT
(BCCMP cont'd.)		
j. 60"		Per Linear Foot (L.f.)
k. 66"		L.f.
l. 72"		L.f.
m. 78"		L.f.
n. 84"		L.f.
22. Bituminous Coated Corrugated Metal Pipe Arch with Pave Invert		
a. 17" x 13"		L.f.
b. 25" x 16"		L.f.
c. 29" x 18"		L.f.
d. 36" x 22"		L.f.
e. 42" x 27"		L.f.
f. 50" x 31"		L.f.
g. 58" x 36"		L.f.
h. 65" x 40"		L.f.
i. 72" x 44"		L.f.
23. Standard Inlets		
a. A-5		each (ea.)
b. A-10		ea.
c. A-15		ea.
d. A-20		ea.
e. B-10		ea.
f. B-15		ea.
g. B-20		ea.
h. C-5		ea.
i. C-10		ea.
j. C-15		ea.
k. D		ea.
l. E		ea.
m. Md. SHA "G"		ea.
n. Md. SHA "J"		ea.
o. Md. SHA "S" Single		ea.
p. Md. SHA "H" Double		ea.
q. Md. SHA "H" Combination		ea.
r. Type "A" Manhole		ea.
s. Type "B" Manhole		ea.

ITEM	IN PLACE UNIT COST	UNIT OF MEASUREMENT
24. WSSC ENDWALL		
a. for 15" pipe		ea.
b. for 21" pipe		ea.
c. for 30" pipe		ea.
d. for 36" pipe		ea.
e. for 42" pipe		ea.
f. for 54" pipe		ea.
g. for 66" pipe		ea.
25. WSSC Cut-off-wall		
a. for 15" pipe		ea.
b. for 21" pipe		ea.
c. for 30" pipe		ea.
d. for 36" pipe		ea.
e. for 42" pipe		ea.
f. for 54" pipe		ea.
g. for 66" pipe		ea.
26. Md. SHA Type "C" Endwall (Roundpipe)		
a. for 15" pipe		ea.
b. for 21" pipe		ea.
c. for 30" pipe		ea.
d. for 36" pipe		ea.
e. for 42" pipe		ea.
f. for 54" pipe		ea.
g. for 66" pipe		ea.
27. Md. SHA Type "E" Endwall (Roundpipe)		
a. for 15" pipe		ea.
b. for 21" pipe		ea.
c. for 30" pipe		ea.
d. for 36" pipe		ea.
e. for 42" pipe		ea.
f. for 54" pipe		ea.
g. for 66" pipe		ea.
28. 6' high permanent chain link fence		Per Linear Foot (L.f.)

APPENDIX B

REGIONAL UNIT COST LIST

COMPILATION OF POND CONSTRUCTION COMPONENT ESTIMATES
DEVELOPED FROM SURVEY RESPONSES TO COG UNIT COST SURVEY

APPENDIX B

REGIONAL UNIT COST LIST

COMPONENT PART/ UNIT	RESPONDENT NUMBER (Random Order) 1	2	3	4	5	6	7	8	9	10	11	12
1 COMM EXCA CY	3.00		5.00	3.00	3.00	2.50	3.00	1.75		1.80	2.25	2.00
2 DITCH EXCA CY			7.00			3.00	6.00	2.50		6.50		5.50
3 COMPACT FILL CY			6.00	3.00	4.50	3.50	3.00	2.25		2.50	3.30	3.30
4 CLEAR AC			2000.00	3500.00		2000.00	3500.00	3600.00	2600.00	1200.00	2750.00	2750.00
5 CLEAR & GRUBB AC			2500.00	4500.00	1800.00	3000.00	4500.00	3600.00		1950.00	3750.00	3750.00
6 SOD SY	2.50	3.00	3.00	3.25		4.00	3.50	2.50	1.40	3.10	4.00	1.00
7 HYDRO SEED AC			2600.00	1500.00			1000.00	1210.00	2178.00	6500.00	1815.00	1815.00
8 SEED MULCH AC	7260.00	8470.00	3450.00	1500.00	4840.00	3630.00	1500.00	1355.00		3900.00	2420.00	1621.00
9 GRVL SHA#2 CY		30.00	14.75	15.00			15.00	8.00	11.00	15.00		
10 GRVL SHA#6 CY			10.00	15.00			15.00	8.00		15.00		
11 GRVL VDHT#57 CY						20.00					25.00	15.00
12 RIPRAP CL # 1 CY	40.00	45.00	120.00	150.00			150.00	60.00		27.00		
13 RIPRAP CL # 2 CY	30.00											
14RIPRAP VDHTCLA CY					36.00	50.00					45.00	45.00
15RIPRAP VDHTCLB CY											55.00	45.00
16 BITUM CURB LF	4.00		6.00		10.00		5.00	4.00	6.00	6.50	12.00	8.00
17 GABION CY			180.00	175.00		130.00	20.00	85.00		23.00	200.00	90.00
18CONC CURB GUTT LF	8.00	10.00	10.00			12.00	10.00	8.00	7.50	8.00	10.00	10.00
19 SUB DRAIN 6" LF	16.00		4.50				12.00	8.00		8.00	10.00	10.00
20 SUB DRAIN 12" LF			8.00	12.00		10.00	15.00	12.00		12.00	15.00	15.00
21CONC FLUME 6" SY			28.00	47.00			50.00	25.00		24.00	60.00	15.00
22LOW CR BEDDING SY				300.00		35.00	300.00	115.00		15.00	165.00	10.00
23ANTI SEEP 12" EA				75.00		300.00	100.00	75.00		600.00	114.00	114.00
24ANTI SEEP 15" EA												
25ANTI SEEP 18" EA				160.00		600.00	200.00	95.00		700.00	189.00	189.00
26ANTI SEEP 24" EA												
27ANTI SEEP 30" EA												
28ANTI SEEP 36" EA				350.00		1350.00	350.00	150.00		900.00		
29ANTI SEEP 42" EA				400.00	1600.00		400.00	185.00	1000.00		437.00	437.00
30 ANTI SEEP 48" EA												
31 ANTI SEEP 54" EA				500.00			500.00	275.00	1100.00		572.00	572.00
32 RISER FAB 18" EA				60.00			100.00	25.00	400.00		130.00	130.00
33 RISER FAB 24" EA												
34 RISER FAB 30" EA												
35 RISER FAB 36" EA				100.00			150.00	110.00	600.00		240.00	240.00
36 RISER FAB 42" EA				125.00			250.00	150.00	800.00		270.00	270.00
37 RISER FAB 48" EA												
38 RISER FAB 54" EA												
39 RISER FAB 60" EA				200.00			350.00	375.00	1200.00		580.00	580.00
40 RISER FAB 66" EA												
41ANTI VORTEX 18 EA				150.00			200.00	50.00	200.00			
42ANTI VORTEX 24 EA												
43ANTI VORTEX 30 EA												
44ANTI VORTEX 36 EA				225.00			250.00	90.00	400.00			
45ANTI VORTEX 42 EA				250.00			350.00	115.00	500.00			
46ANTI VORTEX 48 EA												
47ANTI VORTEX 54 EA												
48ANTI VORTEX 60 EA				350.00			450.00	150.00	600.00			
49ANTI VORTEX 66 EA												
50TEEPEE ANTI 18 EA											235.00	235.00
51TEEPEE ANTI 24 EA												
52TEEPEE ANTI 30 EA												
53TEEPEE ANTI 36 EA											369.00	369.00
54TEEPEE ANTI 42 EA											398.00	398.00
55TEEPEE ANTI 48 EA												

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COMPONENT	RESPONDENT NUMBERS (Random Order)											
PART/ UNIT	1	2	3	4	5	6	7	8	9	10	11	12
56TEEPEE ANTI 60 EA											606.00	606.00
57TEEPEE ANTI 66 EA												
58RCP CL III 15" LF	15.50	23.00	18.00	25.00		21.25		17.00		16.00	23.00	18.00
59RCP CL IV 15" LF	16.00	24.00	19.00	28.00		25.25						
60RCP CL V 15" LF		25.00	20.00	30.00	45.00	32.25		30.00				
61RCP CL III 18" LF	17.50	27.00	20.00	30.00		23.00		19.00		18.00	25.00	22.00
62RCP CL IV 18" LF	18.50	28.00	21.00	33.00		27.00						
63RCP CL V 18" LF		29.00	23.00	35.00	50.00	36.00	35.00					
64RCP CL III 21" LF	19.50	32.00	23.00	35.00		29.00		23.00		23.00	28.00	24.00
65RCP CL IV 21" LF		34.00	24.00	39.00		32.00						
66RCP CL V 21" LF		35.00	26.00	40.00	55.00	40.00	40.00					
67RCP CL III 24" LF	30.00	40.00	25.00	40.00		34.75		26.00	33.00	26.00	32.00	27.00
68RCP CL IV 24" LF		41.00	27.00	44.00		36.75						
69RCP CL V 24" LF		43.00	29.00	45.00	60.00	44.75	45.00					
70RCP CL III 27" LF		47.00	29.00	45.00		38.50		28.00		28.00	37.00	32.00
71RCP CL IV 27" LF		48.00	32.00	50.00		42.50						
72RCP CL V 27" LF		53.00	34.00	52.00	65.00	51.50		52.00				
73RCP CL III 30" LF	35.00	48.00	33.00	50.00		48.50		31.00	43.00	25.00	42.00	36.00
74RCP CL IV 30" LF		51.00	35.00	55.00		52.50						
75RCP CL V 30" LF		55.00	37.00	60.00	70.00	59.50	60.00					
76RCP CL III 36" LF		60.00	39.00	60.00		54.50		37.00		30.00	54.00	47.00
77RCP CL IV 36" LF		64.00	40.00	70.00		58.00						
78RCP CL V 36" LF		68.00	42.00	75.00	85.00	65.00	75.00					
79RCP CL III 42" LF		69.00	43.00	70.00		60.75		40.00		42.00	66.00	52.00
80RCP CL IV 42" LF		75.00	45.00	75.00		65.75						
81RCP CL V 42" LF		82.00	47.00	80.00	95.00	71.75	80.00					
82RCP CL III 48" LF		80.00	50.00	75.00		70.50				45.00	82.00	61.00
83RCP CL IV 48" LF		85.00	52.00	80.00		77.50						
84RCP CL V 48" LF		932.00	55.00	85.00	110.00	85.50	85.00					
86RCP CL III 54" LF		88.00	60.00	80.00		83.25		55.00		50.00	102.00	72.00
87RCP CL IV 54" LF		97.00	62.00	90.00		90.25						
88RCP CL V 54" LF		104.00	65.00	95.00	125.00	105.00	95.00					
89RCP CL III 60" LF		101.00	69.00	95.00		105.00		60.00		58.00	128.00	84.00
90RCP CL IV 60" LF		112.00	71.00	105.00		120.00						
91RCP CL V 60" LF		120.00	73.00	110.00	140.00	130.00	110.00					
92RCP CL III 66" LF		115.00	75.00	110.00		125.00		70.00		60.00	155.00	91.00
93RCP CL IV 66" LF		129.00	78.00	120.00		140.00						
94RCP CL V 66" LF		150.00	81.00	125.00	155.00	152.00	125.00					
95 BCCMP 15" LF				15.00		14.00	15.00	16.00		12.00	17.00	16.00
96 AL PIPE 15" LF											14.00	13.00
97 BCCMP 18" LF			21.00	18.00		18.00	18.00	19.00		14.00	21.00	19.00
98 AL PIPE 18" LF											16.00	15.00
99 BCCMP 21" LF				20.00		22.00	20.00	22.00		16.00	24.00	22.00
100 AL PIPE 21" LF											19.00	17.00
101 BCCMP 24" LF			26.00	23.00		26.00	23.00	25.00		22.00	27.00	25.00
102 AL PIPE 24" LF											22.00	20.00
103 BCCMP 30" LF			30.00	28.00		32.00	28.00	31.00		25.00	34.00	31.00
104 AL PIPE 30" LF											34.00	31.00
105 BCCMP 36" LF			35.00	35.00		37.00	35.00	37.00		30.00	40.00	37.00
106 AL PIPE 36" LF											41.00	37.00
107 BCCMP 42" LF			44.00	45.00		42.00	45.00	43.00		40.00	47.00	43.00
108 AL PIPE 42" LF											44.00	40.00
109 BCCMP 48" LF				50.00		48.00	50.00	50.00		45.00	54.00	49.00
110 AL PIPE 48" LF											49.00	45.00
111 BCCMP 54" LF			58.00	60.00		55.00	60.00	60.00		50.00	71.00	65.00

COMPONENT PART/ UNIT	RESPONDENT NUMBER (Random Order)											
	1	2	3	4	5	6	7	8	9	10	11	12
112 AL PIPE 54" LF											70.00	64.00
113 BCCMP 60" LF				70.00		65.00	70.00	63.00		58.00	91.00	83.00
114 AL PIPE 60" LF											77.00	70.00
115 BCCMP 66" LF				78.00		77.00	78.00	65.00		60.00	100.00	91.00
116 AL PIPE 66" LF											85.00	77.00
117 BCCMP 72" LF				95.00		104.00	95.00	68.00		70.00	109.00	99.00
118 AL PIPE 72" LF											128.00	116.00
119 BCCMP 78" LF				105.00		129.00	105.00	70.00		80.00	118.00	107.00
120 AL PIPE 78" LF											139.00	126.00
121 BCCMP 84" LF				120.00			120.00	75.00		90.00	127.00	115.00
122 AL PIPE 84" LF											149.00	136.00
123 BCCMP 17"X13" LF	30.00		22.00	20.00		27.00	20.00	24.00		18.00	19.00	17.00
124 BCCMP 25"X16" LF			25.00	21.00		30.00	23.00	32.00		20.00	22.00	20.00
125 BCCMP 29"X18" LF			32.00	23.00		33.00	25.00	36.00		28.00	26.00	23.00
126 BCCMP 36"X22" LF			38.00	25.00		36.00	30.00	48.00		34.00	30.00	26.00
127 BCCMP 42"X27" LF			43.00	30.00		42.00	38.00	52.00		41.00	37.00	33.00
128 BCCMP 50"X31" LF			55.00	38.00		52.00	48.00	56.00		46.00	44.00	39.00
129 BCCMP 58"X36" LF			62.00	48.00		63.00	55.00	60.00		51.00	60.00	53.00
130 BCCMP 65"X40" LF			69.00	55.00		72.00	65.00	67.00		56.00	101.00	91.00
131 BCCMP 72"X44" LF			76.00	65.00		80.00	75.00	90.00		64.00	113.00	100.00
132CONCRETE CL A3 CY				200.00		250.00					375.00	350.00
133CONCRETE CL A4 CY											425.00	300.00
134 REBARS #3 LF											.40	.25
135 REBARS #4 LF											.35	.20
136 REBARS #5 LF											.30	.15
137FNC CHAIN H=6' LF	9.00			8.00			10.00	11.00			10.00	10.00
138BLK 8"X12"X12" EA											12.00	12.00
139BLK 8"X 8"X12" EA											10.00	10.00
140BLK 6"X 8"X12" EA											9.00	9.00
141 !NLET A-5 EA	1525.00	1550.00	1400.00	1700.00			1700.00	1100.00		1500.00		
142 INLET A-10 EA	2200.00	1700.00	1900.00	2000.00			2000.00	1400.00	3600.00	1800.00		
143 INLET A-15 EA		1800.00	2200.00	2300.00			2300.00	1700.00	4100.00	2300.00		
144 INLET A-20 EA	2250.00	1900.00	2600.00	2800.00			2600.00	2100.00		3000.00		
145 INLET B-10 EA	1900.00	1500.00	2000.00	1800.00			1800.00	1500.00		2850.00		
146 INLET B-15 EA	2588.00	1750.00	2400.00	2100.00			2100.00	1800.00		3200.00		
147 INLET B-20 EA	3155.00	1800.00	2800.00	2600.00			2400.00	2100.00		3800.00		
148 INLET B-20 EA												
149 INLET C-5 EA				2000.00			2000.00			1600.00		
150 INLET C-10 EA				2500.00			250.00			1900.00		
151 INLET C-15 EA				3000.00			3000.00			2400.00		
152 INLET D EA			1500.00				1000.00	900.00		1200.00		
153 INLET E EA	1000.00		1400.00				800.00	1100.00		1400.00		
154 SHA INLET G EA							1800.00	1500.00	550.00	1800.00		
155 SHA INLET J EA			1800.00	1500.00			1500.00	1950.00		2000.00		
156SHA INLET 1 S EA			2200.00	1500.00			1500.00	1800.00		2400.00		
157SHA INLET 2 H EA			2800.00	2000.00			1800.00	2500.00		2200.00		
158SHA INLET CO H EA			2800.00	2000.00			2000.00	2300.00		3800.00		
159 MANHOLE TYP A EA			2800.00	2500.00			2000.00	1200.00		1900.00		
160 MANHOLE TYP B EA	1900.00		2800.00	2500.00			2500.00	1500.00		2000.00		
161WSSC END 15" EA		800.00	450.00	500.00			5000.00	300.00		600.00		
162WSSC END 18" EA												
163WSSC END 21" EA		1300.00	500.00	725.00			700.00	375.00		850.00		
164WSSC END 24" EA												
165WSSC END 30" EA		1900.00	650.00	1200.00			1200.00	500.00	1200.00	1200.00		
166WSSC END 36" EA		2500.00	875.00	2000.00			1900.00	1000.00		1400.00		

RESPONDENT NUMBER (Random Order)

COMPONENT PART/ UNIT	1	2	3	4	5	6	7	8	9	10	11	12
167WSSC END 42" EA		3000.00	1000.00	2350.00			2300.00	1250.00		1700.00		
168WSSC END 48" EA												
169WSSC END 54" EA		3600.00	1200.00	3325.00			3200.00	2000.00		2200.00		
170WSSC END 66" EA		2500.00	1500.00	4325.00			4200.00	2600.00		2700.00		
171WSSC END 72" EA												
172WSSC CUT 15" EA		300.00	250.00	150.00			200.00	175.00		525.00		
173WSSC CUT 18" EA												
174WSSC CUT 21" EA		375.00	300.00	160.00			300.00	200.00		850.00		
175WSSC CUT 24" EA												
176WSSC CUT 30" EA		475.00	450.00	250.00			350.00	250.00		1050.00		
177WSSC CUT 36" EA		575.00	875.00	300.00			400.00	325.00		1260.00		
178WSSC CUT 42" EA		600.00	1000.00	400.00			450.00	375.00		1470.00		
179WSSC CUT 48" EA												
180WSSC CUT 54" EA		700.00	1200.00	575.00			55 0.00	450.00		1890.00		
181WSSC CUT 66" EA		900.00	1500.00	775.00			750.00	525.00		2310.00		
182SHA C END 15" EA			450.00	200.00			300.00	300.00		555.00		
183SHA C END 21" EA			500.00				400.00	375.00		775.00		
184SHA C END 30" EA			600.00	600.00			600.00	500.00		1110.00		
185SHA C END 36" EA			875.00	1000.00			1000.00	1000.00		1330.00		
186SHA C END 42" EA			1000.00	1250.00			1300.00	1250.00		1550.00		
187SHA C END 54" EA			1200.00	2100.00			2100.00	2000.00		2000.00		
188SHA C END 66" EA			1500.00				2500.00	2600.00		2440.00		
189SHA E END 15" EA	250.00		475.00	250.00			400.00	300.00		575.00		
190SHA E END 21" EA	300.00		600.00				500.00	400.00		805.00		
191SHA E END 30 EA	400.00		950.00	700.00			700.00	625.00		1150.00		
192SHA E END 36 EA			1200.00	1200.00			1200.00	1250.00		1380.00		
193SHA E END 42 EA			1350.00	1700.00			1700.00	1500.00		1610.00		
194SHA E END 54 EA			1500.00	2500.00			2500.00	2250.00		2070.00		
195SHA E END 66 EA			1700.00				3000.00	2750.00		2530.00		
196 BTUM FLUM 6" SY												
197 CMP FAB END EA												
198 ANTI SEEP 72" EA												
199 MANHOLE FIN EA												
200 RCP CLIII 72" LF												
201 STD INLT MOD EA												
202 INLE AGL IRON LF												
203 4" ASPH PAV. SY												
204 SHA E END 27" EA												
205 ANTI SEEP 21" EA												
206 RCP CLIII 12" LF												
207ANTI VORTEX 72 EA												
208 BCCMP 96" LF												
209 ANTI SEEP 96" EA												
210 RCP CLIV 12" LF												
211 SUBDRAIN 9" LF												
213ANTI VORTEX 90 EA												
214 TYPAR CLTH SY												
215 RISER FAB 72" EA												
216ANTI VORTX 102"EA												
217ANTI VORTEX 78"EA												

APPENDIX C

LIST OF PERSONS/ORGANIZATIONS CONSULTED IN COG STORMWATER MANAGEMENT POND O&M ANALYSIS

APPENDIX C

LIST OF PERSONS/ORGANIZATIONS CONSULTED IN O&M ANALYSIS

INDIVIDUALS CONTACTED	ORGANIZATION	PHONE
Greg Bayor	City of Rockville, Md. Dept. of Recreation	(301) 424-8000
Roy Benner	Maryland Water Resources Administration	(301) 269-2224
Calvin Bolls	Virginia Dept. of Transportation	(804) 786-2534
Ed Boone	WSSC - Washington Suburban Sanitary Comm.	(301) 699-4828
Patrick Brunett	Southeast Michigan Council of Governments	(313) 961-4266
Mike Culpepper	City of Troy, Mich.	(313) 524-3385
John Davis	Monroe County, N.Y.	(716) 428-5577
Bill Degroot	Urban Drainage & Flood Control District, Denver, Colorado	(303) 455-6277
Bruce Dunn	U.S. Army Corps of Engineers Washington Military District	(202) 693-8394
Linda Haghighat	Dept. of Public Works of Howard County, Md.	(301) 992-2388
Jack Helm	Howard County Soil Conservation District, Md	(301) 465-3180
J. L. Jalali	M-NCPPC, Montgomery County, Dept. of Parks and Recreation, Md	(301) 565-7420
Mr. U. Kirste	Prince William County Dept. of Public Work, Va	(703) 369-9342
Rod LaFever	City of Rockville, Md. City Engineer	(301) 424-8000
Dave Lindquist	City of Troy, Mich.	(313) 524-3385
Sam Martin	Baltimore Regional Planning Council, Md	(301) 383-5838
Dave Morrison	Southeast Michigan Council of Governments	(313) 961-4266

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INDIVIDUALS CONTACTED	ORGANIZATION	PHONE
Larry Muggler	City of Denver - COG	(303) 455-6277
Jim Murray	Washington County, Mich. Drain Commissioner	(313) 994-2525
John Phiphart	Montgomery Village Foundation, Md.	(301) 948-0110
Charles Rodehamel	Columbia Parks and Recreation, Md.	(301) 997-7022
Jerry Seally	Virginia State Soil Conservation Service	(804) 786-2064
Charles Smith	U.S. Army Corps of Engineers	(202) 272-0395
Jim Stewart	City of Rochester, N.Y.	(716) 342-9000
Stuart Terrett	Fairfax County, Virginia	(703) 691-2882
Richard Thomasin	WSSC	(301) 699-4420
Cliff Tottle	City of Winnipeg, Canada - Manitoba Waterworks, Waste and Disposal Division	(204) 237-4203
J. Toby Tourbier	Urban Land Institute Univ. of Delaware	(302) 738-2191
Terry Way	Salt Lake City, Utah NURP Coordinator	(801) 535-7210
Lewis Williams	Dept. of Environmental Protection, Montgomery County, Md	(301) 251-2360
Harold Williamson	Fairfax County Dept. of Public Works, Va	(703) 691-2581
Bud Worthington	Kettler Brothers, Inc. Land Developer, Gaithersburg, Md.	(301) 948-4000
Douglas Wrenn	Urban Land Institute	(202) 289-8500
Glenn Yrjanainen	Oakland County, Mich.	(313) 858-0981

INDIVIDUAL CONTACTED	ORGANIZATION	PHONE
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Nancy Dentz	American Academy of Environmental Engineers	(301) 261-1820
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Dave Garcia	Mid America Regional Council, Kansas City, Mo.	(816) 474-4240
Dr. Al Geis	Dr. Al Geis Patuxent Wildlife Research Center	(301) 776-4880
Jerry Hammond	Sterling Hgts. MI, City Engineer	(313) 977-6222
Don Hey	Northeast Illinois Planning and Development Commission	(312) 454-0400
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James Meredith	City of Independence, Mo. City Engineer	(816) 836-8300
John Pettit	Pettit and Griffin Builders, Montgomery Co., Maryland	(301) 340-7170
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Myron Rosenburg	Camp, Dresser and McKee, Environmental Engineers	(617) 890-1201
John Tettemer	L.A. County Flood Control District, Chief Deputy, California	(213) 226-4111
Bob Thoronson	Environmental Protection Agency - Implementation Branch, Washington, DC	(202) 755-6023
Bob VanWyk	Fresno Flood Control District - Fresno, CA	(209) 485-6330
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Jim Magill	Md. State Highway Admin., Salisbury, Maryland	(301) 742-2101
Tom Pierce	Leon County, Fla., Dept. of Planning	(904) 488-6133
Irwin Riessler	National Assoc. of Urban Flood Management Agencies	(202) 293-4844
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Col. W. Smith	Fairfax County, DPW, Va.	(703) 691-2402
Carter Wilson	Md. State Highway Admin., Accounting	(301) 659-1605

APPENDIX D

MONTGOMERY COUNTY, MD. DETENTION STORAGE REQUIREMENTS, 2-YEAR DESIGN STORM, SCS STORMWATER MANAGEMENT COST STUDY

Detullio and Thomas, SCS
July, 1977

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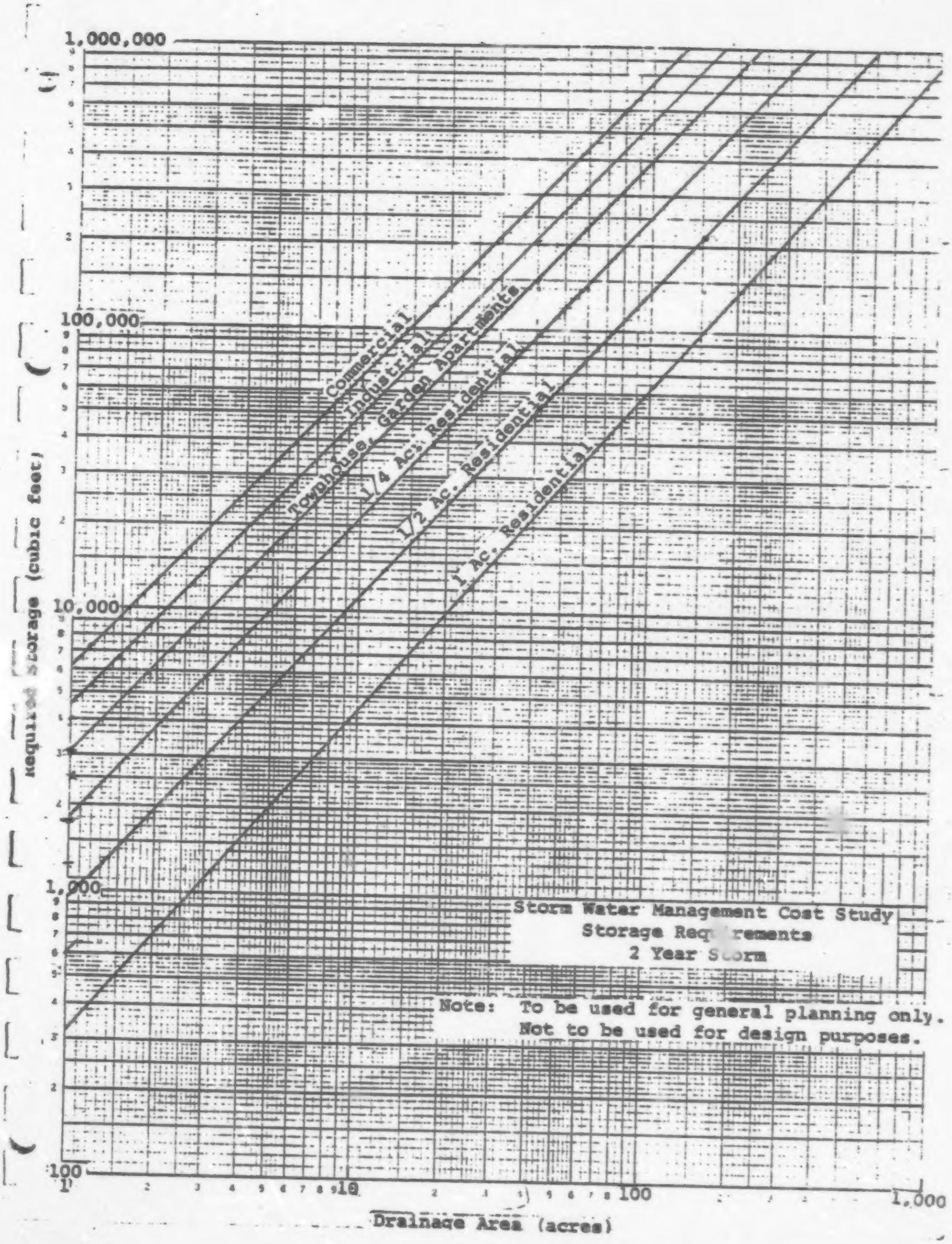

Storm Water Management Cost Study
Storage Requirements
2 Year Storm

Note: To be used for general planning only.
Not to be used for design purposes.

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APPENDIX E

FAIRFAX COUNTY DESIGN MANUAL FOR BMP FACILITIES

FAIRFAX COUNTY
DEPARTMENT OF ENVIRONMENTAL MANAGEMENT
FAIRFAX COUNTY, VA.

August, 1980

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(PRELIMINARY)
DESIGN MANUAL
FOR
BMP FACILITIES

Department of Environmental Management
Fairfax County, Virginia
August, 1980

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INTRODUCTION

On July 14, 1980 the Fairfax County Board of Supervisors adopted an amendment to the Public Facilities Manual, Volume 1 requiring Best Management Practices (BMPs) be implemented in the Occoquan Basin Watershed in order to protect the County's water supply. "Best Management Practices" shall be applied to all pending preliminary plats in the residential area and all commercial and industrial site plans not yet approved in the Occoquan Watershed. A copy of that Amendment is attached as Enclosure No. 1.

The purpose of this Design Manual is to provide designers with some guidance as to how to meet this new requirement. The state of the art in this field is in its infancy and future modifications will be necessary as knowledge grows. Designers are strongly encouraged to help find better practical solutions for obtaining the goal of a cleaner storm water runoff at minimum cost.

The technological strategy put forth here was principally derived from the report entitled "Guidebook for Screening Urban Nonpoint Pollution Management Strategies" prepared by the Regional Resources Division of the Northern Virginia Planning District Commission, 7309 Arlington Boulevard, Falls Church, Virginia 22042; (703) 573-2210; November, 1979.

This strategy avoids the usage of performance standards related to effluent standards. Instead, it establishes a suggested minimum percentage of the development site acreage which should be served by an acceptable BMP, and relates a long-term (40-hour drawdown time) storage volume to be provided with any proposed land use.

The design parameters set forth in this guidebook were the result of various pollutant monitoring studies performed in the Washington area, computer model studies using literature values for sediment deposition rates and various sanitary land treatment studies. It is suggested for those who desire more details regarding the technological basis for the guidelines used here that they contact the Northern Virginia Planning District Commission at the address listed above.

GENERAL DESIGN GUIDELINES*

1. Maximize aerial coverage of on-site drainage area with BMP's (suggested minimum is 70% of the site).

2. Minimize on-site impervious area.

   - o Preserve natural wooded cover, open space, and green-ways on site.

   - o Pervious surfaces such as modular pavement, porous pavement, and gravel are considered BMP's. (If additional impervious areas are discharged to these surfaces, a 20 to 1 ratio of impervious to pervious areas is acceptable without further analysis. Larger ratios should be justified with an infiltration or void ratio design.)

3. Where existing development upstream does not have BMP's, providing BMP's to cover offsite upstream existing development may be used in lieu of BMP requirements on-site. (That is, a compensating design controlling runoff pollution from offsite to compensate for the on-site uncontrolled pollution.)

4. Promote natural infiltration wherever possible since high removal of pollutants can be achieved through natural biological, physical, and chemical processes within the soil profile.

   - o Divert impervious area flow to pervious areas before entrance to a stream or drainage facility.

     For example:

     - o roof downspouts to pervious lawns; and

     - o curb stops in parking areas (as opposed to curb and gutter) and appropriate grading to disperse runoff to wooded and vegetated areas.

     Note: To operate effectively, vegetated surfaces of overland flow BMP's should be 100-150 feet in length at 2-6% slopes, respectively based on land application of wastewater literature.

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* Note: Where these guidelines conflict with normal storm water design criteria the normal storm water design criteria would govern unless specific approval is obtained from the Director.

5. Avoid locating structural BMP's (except for wet (retention) ponds) in natural stream channels with substantial offsite upstream drainage areas (either developed or undeveloped).

   - When placed in such a channel, provide extra storage to allow for natural stream erosion.*

   - Design structural BMP controls to facilitate maintenance particularly access. See also general maintenance considerations.

6. Timing of Controls: in most instances it would be preferable to delay BMP construction until all other land disturbing activities are complete. Otherwise a final cleanout before acceptance must be specified.

7. Minimize attractive nuisance of BMP's, e.g. by locating at reasonable distances from residences.

8. Wherever structural controls are used, VOLUME controls (i.e. controls which depend on infiltration) should be the most favored device. In recognition of their greater effectiveness a credit of 50% may be taken when they are used; that is, reduce the Chart A value by half, when designing a volume control.

   - Line gravel trenches on sides and on the top near gravel surface with a commercially available filter cloth material such as TYPAR to prevent clogging of void space in trenches.

   - The top layer of filter cloth should be near the gravel surface so that the material can be readily cleaned or replaced.

9. Detention and Retention Ponds.

   - Detention/Retention basin BMP's are dry/wet ponds that rely on solid settling processes to remove sediment and suspended pollutant loading. Retention ponds will normally be considered BMPs without further modification if the permanent body of water exceeds three times the BMP storage requirement from Chart A.

   - Provide a L:W ratio in the pond of at least 2:1 - 3: 1, and maximize the distance between pond inflow and outflow.

   - Use water tolerant species of vegetative cover for pond surfaces (also overland and swale drainage areas) to maintain high infiltration rates, break up the soil profile for filtration and aid decomposition of settled particles during the drying cycle, and thus prevent resuspension of settled pollutants. Forage and fodder crops, such as reed canary grass, fescue, perennial rye, orchard grass, and bermuda grass can be used successfully to treat large amounts of runoff, and are tolerant of variations in water quality.

---

* See the Department of Environmental for additional guidelines in this area.

o At inflow points to detention points use energy dissipators such as riprap, to disperse and slow down flow in the upstream end of the basin, thereby promoting settling and minimizing resuspension of settled pollutants. In some instances, designers may want to consider channelizing flow from incoming pipes to the upstream end of the pond in order to maximize the travel time through the pond. However, do not construct paved base-flow channels.

o Outlet Controls: suggest underdrains for final drainage of all ponds and they may be used for the principal BMP outlet if properly designed.

o Outlet controls should be sized to release water at a rate producing an approximately 40-hour drawdown time. It is suggested that 1/2" - 1" diameter holes for orifice sizes be used on perforated risers.

o To prevent clogging, around a perforated vertical riser outlet structure, place either a cone of gravel or a non-corrosive fine-mesh screen mounted at a radius several inches greater than the riser radius.

o Suggest installing a concrete pad at the base of the outlet riser for stability and ease of maintenance.

10. Other Structural Controls:

o For underground vaults and pipes, size manhole or drop box sufficiently large to have access for maintenance equipment. See also general maintenance checklist.

GENERAL MAINTENANCE CONSIDERATIONS

The maintenance impact of storm water management - BMP facilities is considered to be of primary concern to Fairfax County and to the future operations of these facilities. Designers are strongly urged to keep maintenance and operation in their design considerations of these facilities.

The following are suggested minimums which should be included in design considerations:

- Access for maintenance and operation for vehicles and equipment. Generally a clear access of 20 feet wide should be provided.
- Proximity of facilities to public right-of-way is encouraged in order to minimize the length of access-ways.
- Multiple accesses are desired on major facilities.
- Special access easement agreements to preclude planting of shrubs, construction of fences and other obstructions are to be used. (Standard drainage easement agreements are not acceptable for access to major storm water management facilities.) See the Department of Environmental Management for this form.
- Grading of access way to facilities and grading around facilities should provide slopes that will accommodate maintenance and operating vehicles safely.
- Major facilities including wet ponds, underground chambers, etc. should provide at least one all-weather access roadway to include a minimum of 10-foot wide, 4" thick gravel surface.
- As these facilities are generally in close proximity to dwellings and may be subject to vandalism, principal spillways and other devices should be designed to minimize tampering. For example, manholes should be secured by locks.
- Safety should be a factor in design for operation and maintenance of facilities. For example, on any slopes to be maintained by mowers, the slopes should not exceed 3:1.
- Underground chambers should provide for more than one access point for ventilation in cleaning and be large enough to

accommodate cleaning equipment (at least one opening of 60" of diameter). Generally the minimum height where possible should be 72" to facilitate maintenance.

SPECIFIC DESIGN STEPS

Step No. 1: Measure area of site draining into Occoquan Watershed. Measure per cent of impervious area proposed to be constructed (or use general zoning values from Chart 1 of Volume 1 of the Public Facilities Manual) to obtain an entering value for Chart A to determine the amount of BMP storage desired for this site.

Step No. 2: Where a structural BMP control, which lends itself to a computational design, is proposed, measure the impervious area proposed on-site within the watershed controlled by the proposed facility. (Include offsite impervious areas if already developed without BMP controls and the designer desires to take credit for this storage, see General Design Guidelines number 3) to obtain an entering value for Chart A to determine the amount of BMP storage needed for this facility.

Note: Where undeveloped land offsite drains through the facility, the designer of this facility is encouraged to oversize this facility to meet the offsite BMP (and quantity control) requirements. This would represent a benefit to the upstream property owner(s) which perhaps could be sold to him now or in the future.

If Step No. 2 ≥ No. 1 Design is acceptable. However proceeding to Step No. 3 to maximize coverage is encouraged.

If Step No. 2 < No. 1 Proceed to Step No. 3.

Step No. 3: In the uncontrolled areas, measure all open areas, sheet flow areas and impervious areas draining to pass slowly over pervious areas and take half credit for this total area as being under BMP control. This value would be in acres which could then be multiplied times the cubic feet storage/acre value used in Step No. 1 to convert this value to cubic feet.

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Step No. 4: Adjust the Step No. 2 value accordingly. That is, Step No. 2 value plus Step No. 3 value = Step No. 4 value. If Step No. 4 value ≧ 70% Step No. 1 value, then this design is acceptable; if not, add more pervious sheet flow areas, additional BMP facilities or apply to Director for partial waiver of site requirements, with reasons for justifications.

BMP FACILITY DESIGN FORMAT

Step No. 1: (A) Area of site draining into Occoquan Watershed ____ acres.

(B) Area of proposed impervious cover for subject site ____ acres.

(C) % of site to be impervious $\left[\frac{(B)}{(A)} \times 100\right] =$ ____ % impervious.

or general zoning value from Chart 1 PFM ____ % impervious.

or ____ "C" Factor.

(D) Chart A value for BMP storage/acre ____ cf/acre.

(E) Total BMP storage required $\left[(A) \text{ times } (D)\right] =$ ____ cf.

Step No. 2: (A) Measure the on-site (and offsite if credit is to be taken for it) areas draining to the proposed BMP facility. ____ acres.

(B) Measurement of impervious area on-site (and offsite if credit is to be taken for it) which drains to the proposed BMP facility. ____ acres.

(C) % of the on-site (and offsite if credit is to be taken for it) drainage area to the proposed facility. $\left[\frac{(B)}{(A)} \times 100\right] =$ ____ % impervious.

(D) Chart A value for BMP storage/acre ____ cf/acre.

(E) Total BMP storage required for this proposed BMP facility. $\left[(A) \times (D)\right] =$ ____ cf.

(Note: Repeat Step 2 for each proposed BMP facility).

Decision Plateau:

- Step No. 2 (E) ______ cf $\begin{matrix}(\geq)\\(<)\end{matrix}$ Step No. 1 (E) ____ cf.
- If Step No. 2 (E) ≥ No. 1 (E) Design is acceptable. (Note: even where this condition is met, designers are encouraged to proceed to Step No. 3 in order to maximize site coverage).
- If Step No. 2 (E) < No. 1(E) Proceed to Step No. 3.

Step No. 3: (A) In the uncontrolled areas, measure all open areas, sheet flow areas and impervious areas draining to pass slowly lover pervious areas. ________acres.

(B) Multiply (A) x 50% ________acres.

(C) Multiply No. 3(B) x No. 1 (D) = ________cf.

Step No. 4: Step No. 2(E) plus Step No. 3(C) = ________cf.

Decision Plateau:

- Step No. 4 ______; 70% x Step No. 1(E) ________.
- If Step No. 4 ≥70% x Step No. 1 (E), design is acceptable.
- If Step No. 4 is less than 70% of Step No. 1(E), then add additional BMP facilities Step No. 2 or more pervious sheet flow areas Step No. 3 or apply to the Director for partial waiver of BMP site requirements with reasons for justification.

BMP FACILITY BASIC DATA FORM

Project Name ____________ Tax Map Location* ____________

Certifying Engineer ________ Date ____________

Type of BMP Facility

	BMP Volume Storage (net)	2-Yr storage	10-Yr storage
Pond	____________	________	________
Infiltration facility	____________	________	________
Other			
________	____________	________	________

Type of Outlet**

	For BMP Facility	For 2-Yr SWM	For 10-Yr SWM
Type (e.g. underdrain, riser, etc.)	____________	________	________
Opening Size(s)	____________	________	________
Invert Elevation	____________	________	________
Maximum water surface ELEvaTIOn to BMP, 2- or 10-year levels	____________	________	________

(100-year w.s. elevation ________).

---

* Submit 8-1/2" x 11", 200' to the inch locational map with landmarks showing BMP facility locations; and

** Submit on 8-1/2" x 11" a detail of the outlet works (for use by maintenance forces).

BMP FACILITY BASIC DATA FORM (cont.)

Maintenance Considerations

Access to the facility* ____________ ____________
from public roadway through private property

Special access easement ____________
DB PG

Responsible maintaining party ____________

Maintenance Agreement recorded ____________
DB PG

Suggested maintenance instructions ____________

____

Are there upstream offsite undeveloped areas draining through this facility?

Yes ____________ . No ____________.

If yes please specify tax map location(s) ____________ and if the offsite owner/developer was contacted for possible cooperation on the funding of a larger facility to serve offsite as well as on-site requirements?

____________ ____________.
location party contacted

____________ ____________
County follow-up Date

____
Action taken

---

* Show access locations on the location map.

In accordance with the Board of Supervisors' desire to monitor closely the costs of BMP facilities, designers and developers are strongly encouraged to supply the County with the following additional cost data:

COST*

Estimated				Actual**			
Quantity	Item	Unit Cost	Total Cost	Quantity	Item	Unit Cost	Total Cost
Totals							

Contractor ____________ Time period under construction ____________

Comments ____

____

____

____

---

* Where it is possible to separate the BMP portion from the rest of the Storm Water Management requirements, please do so. If not, please give an estimated BMP % of the total.

** To be submitted at time of as-built with records as best as reasonably available.

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EXAMPLE #1

EXAMPLE OF BMP DESIGN USING PFM DETENTION POND EXAMPLE

GIVEN: A hypothetical 10-acre site to be developed into a commercial shopping center.

From Chart A using the "C" factor of o.9 for Commercial we obtain 3100 cf/acre or 10 AC x 3100 cf/acre = 31,000 cf of long term (40 hour drawdown) storage required.

Try basic dimensions of 75' x 150' (N.B.use long dimension to lengthen inflow travel path.)

$$\text{Area} = 75' \times 150' = 11{,}250 \text{ sf};$$

$$\text{therefore depth} = \frac{31{,}000}{11{,}250} = 2.75'$$

To size openings in outflow pipe -- use 6" ø underdrain pipe 10' long

For a 40-hour draindown time the average outflow rate would be:

$$Q \text{ (average outflow)} = 31{,}000 \text{ cf} \times \frac{1}{40 \text{ hrs} \times 3600 \text{ sec/hr}}$$

$$= 0.215 \text{ cfs}$$

If the top of this 6" ø is 9" below grade, then the maximum head to the center of this pipe would be:

$$h = \frac{6"ø}{2} + 9" + 2.75' = 3.75$$

Assuming average outflow rate at average depth; i.e.

$$h \text{ (average)} = \frac{3.75'}{2}$$

$$Q \text{ outflow} = CA\sqrt{2gh} \text{ (average)} = .6 \times A \times \sqrt{64.4 \times \frac{3.75'}{2}}$$

$$= 0.21\ 5 \text{ cfs}$$

∴ required orifice area = 0.0326 sf

Area of one ½" diameter hole = 0.00136 sf/hole

∴ use .0326/.00136 = 23.97 holes

Say 8 sets in 3 rows spaced 1' apart
see drawing for details

This completes the design for the BMP portion of this detention pond: now proceed to the peak shaving portion in the following manner.

Predeveloped runoff: C=0.30 TC = 15 minutes I (2 yr) = 3.5"/hr
I (10 yr) = 5.1"/hr

$$\therefore Q\ (2\ yr) = 0.30 \times 10\ Ac \times 3.5 = 10.5\ cfs$$
$$Q\ (10\ yr) = 0.30 \times 10\ Ac \times 5.1 = 15.3\ cfs$$

Runoff after development: C = 0.90 TC = 5 minutes I (2 yr) = 5.1"/hr
I (10 yr) = 7.1"/hr

$$\therefore Q\ (2\ yr) = 0.90 \times 10\ Ac \times 5.1 = 45.9\ cfs$$
$$Q\ (10\ yr) = 0.90 \times 10\ Ac \times 7.1 = 63.9\ cfs$$

The graphical (or approximate) design procedure shows that all of the 2 yr storm runoff will be stored in the 31,000 cf BMP area for the first 18 minutes. That is, 18 minutes is required to fill the first 2.75' of depth. An additional depth of 1.0' will be required to supply the required additional storage of 11,000 cf;

11,000 cf/11,250 sf = 1.0'

If we use a 6" high throat for a control orifice the required area would be:

$$Q = CA\sqrt{2\ gh} = .6xAx\sqrt{64.4\ x\ .75} = 10.5\ cfs$$

$$\therefore A = 2.5\ sf/use\ 6"\ throat\ 5'\ long$$

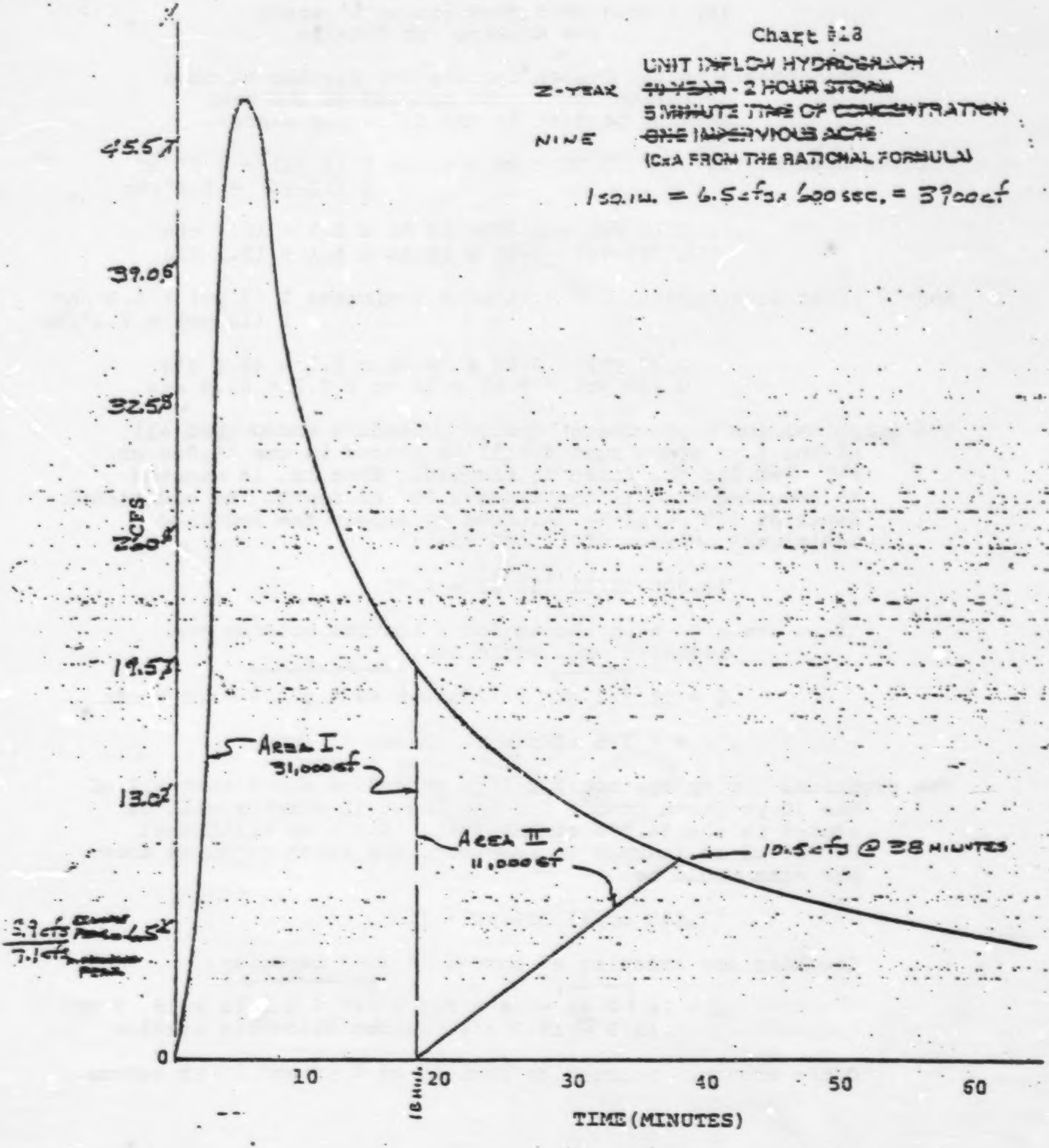
The graphical (or approximate) design procedure shows that all of the 10 yr storm runoff for the first 12 minutes will be stored in the 31,000 cf BMP area. Since an additional 22,000 cf of storage is required, the depth required above BMP area would be:

$$22{,}000\ cf/11{,}250\ sf \cong 2.0'$$

Checking the existing 6" throat 5' long capacity:

$$Q = CA\sqrt{2\ gh} = .6 \times 2.5 \times \sqrt{64.4 \times 1.75} = 15.\ 9\ cfs$$
$$15.9 \cong 15.3\ cfs\ maximum\ allowable\ outflow$$

Close enough; proceed to routing of 2 yr and 10 yr storms.



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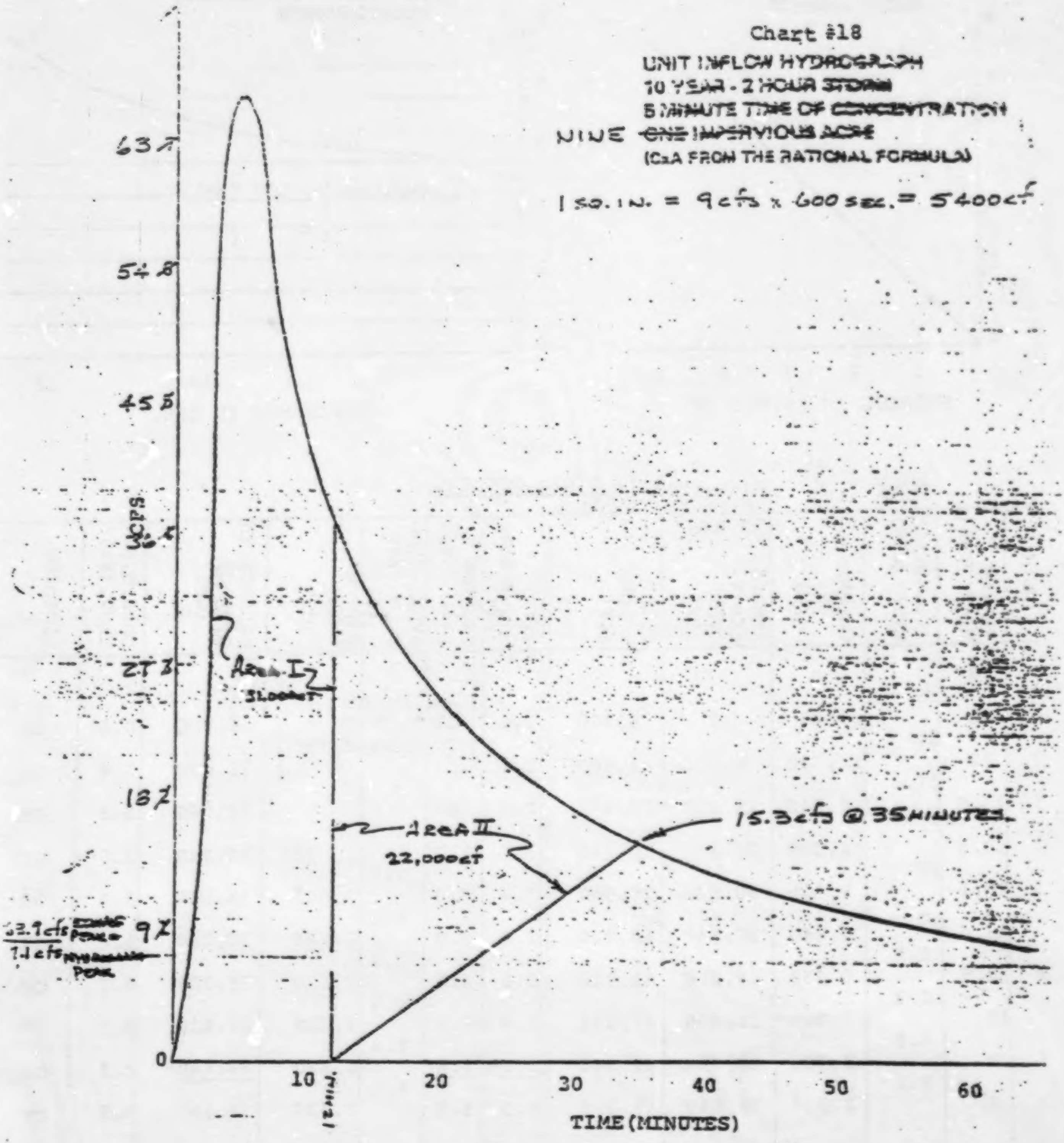

Chart #18

UNIT INFLOW HYDROGRAPH
10 YEAR - 2 HOUR STORM
5 MINUTE TIME OF CONCENTRATION
NINE ~~ONE~~ IMPERVIOUS ACRE
(CxA FROM THE RATIONAL FORMULA)

1 SQ. IN. = 9 cfs x 600 sec. = 5400 cf

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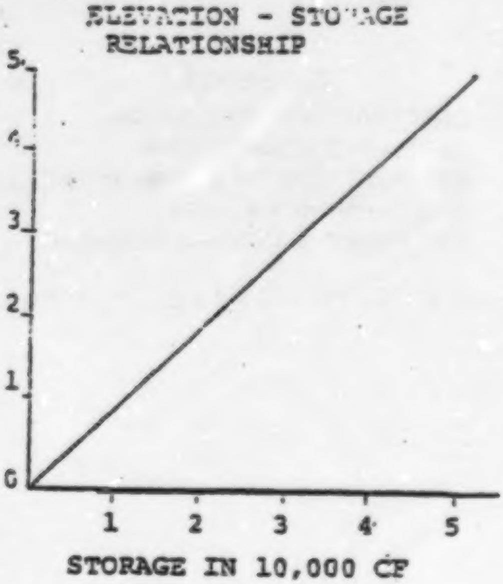
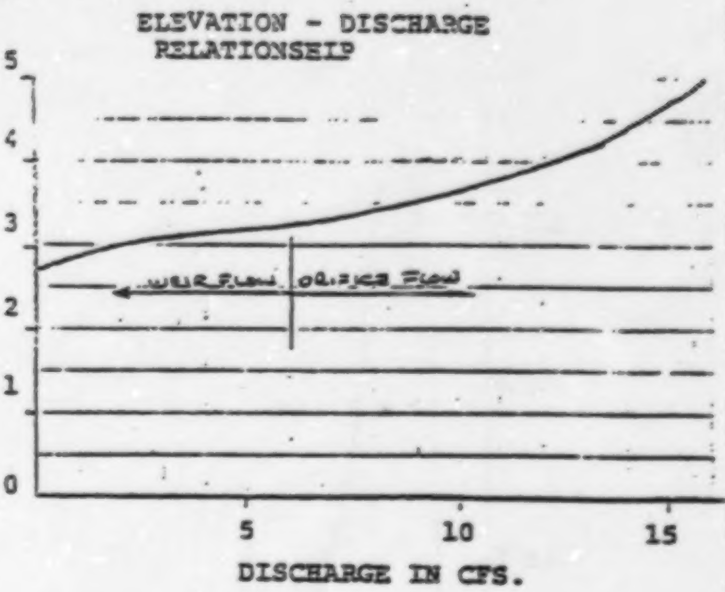


ELEVATION - STORAGE RELATIONSHIP



ELEVATION - DISCHARGE RELATIONSHIP

2-YR STORM ROUTING

col 1 / col 2 | x̄ inflow (cfs) 300 | col 4(c) New inflow (col 3) | Col 3 + Col 4 | or Σ V_s

(MIN)	INFLOW RATE (CFS)	AVE. INFLOW RATE (CFS)	VOLUME IN (CF)	STORAGE CARRY-OVER (CF)	TOTAL VOLUME (CF)	TRIAL W.S. ELEV. (FT)	OUTFLOW RATE (CFS)	AVER. OUT-FLOW RATE (CFS)	VOLUME OUT (CF)	BALANCE IN STORAGE (CF)	CORR. W.S. ELEV. (FT)	DECISION
0	0		0									
.5		23										
5	46		6,900	0	6,900	0.6'	ASSUME NO OUTFLOW UP TO ELEV. 2.75			6,900	0.6'	OK
		39										
0	32		11,700	6,900	18,600	1.6				18,600	1.6	OK
		27.8										
5	23.5		8,340	18,600	26,940	2.5	0			26,940	2.5	OK
		21						1.0				
0	18.5		6,300	26,940	33,240	3.0	2.0		300	32,940	3.0	OK
		17						5.0				
5	15.5		5,100	32,940	38,040	3.4	8.0		1,500	36,540	3.3	OK
		14.2						8.4				
0	13.0		4,260	36,540	40,800	3.5	8.8		2,520	38,280	3.4	OK
		12.2						8.8				
5	11.5		3,660	38,280	41,940	3.5	8.8		2,640	39,300	3.5	OK
		10.8						9.1				
0	10		3,240	39,300	42,540	3.6	9.4		2,730	39.810	3.5	OK
		9.5						9.4				
5	9		2,850	39,810	42,660	3.6*	9.4*		2,820	39,840*	3.5	OK
		8.5						9.1				
0	8		2,550	39,840	42,390	3.5	8.8		2,730	39,660	3.5	OK

* THEREFORE MAXIMUM STORAGE IS 39,840 CF; MAXIMUM DEPTH IS 3.6'; AND MAXIMUM OUTFLOW IS 9.4 CFS. (< 10.5 CFS ALLOWABLE ∴ OK)

10 - YR. STORM ROUTING

(MIN)	INFLOW RATE (CFS)	AVE. INFLOW RATE (CFS)	VOLUME IN (CF)	STORAGE CARRY-OVER (CF)	TOTAL VOLUME (CF)	TRIAL W.S. ELEV. (FT)	OUTFLOW RATE (CFS)	AVER. OUT-FLOW RATE (CFS)	VOLUME OUT (CF)	BALANCE IN STORAGE (CF)	CORR. W.S. ELEV. (FT)	DECISION
0	0		0									
		32										
5	64		9,600	0	9,600	0.8'	ASSUME NO OUTFLOW UP TO ELEV. 2.75'			9,600	0.8'	OK
		54										
0	44		16,200	9,600	25,800	2.3	0			25,800	2.3	OK
		38						2.5				
15	32		11,400	25,800	37,200	3.2	5		750	36,450	3.2	OK
		29						7.5				
20	26		8,700	36,450	45,150	3.7	10		2250	42,900	3.8	OK
		23.8						11.5				
25	21.5		7,140	42,900	50,040	4.2	13		3450	46,590	4.1	OK
		19.7						13.3				
30	18		5,910	46,590	52,500	4.3	13.6		3990	48,510	4.3	OK
		16.5						13.8				
35	15		4,950	48,510	53,460	4.4	14.0		4140	49,320	4.4	OK
		14.5						14.0				
40	14		4,350	49,320	53,670	4.4*	14.0*		4200	49,470*	4.4	OK
		13.0						13.8				
45	12		3,900	49,470	53,370	4.3	13.6		4140	49,230	4.4	OK
		11.5						13.6				
50	11		3,450	49,230	52,680	4.3	13.6		4080	48,600	4.3	OK

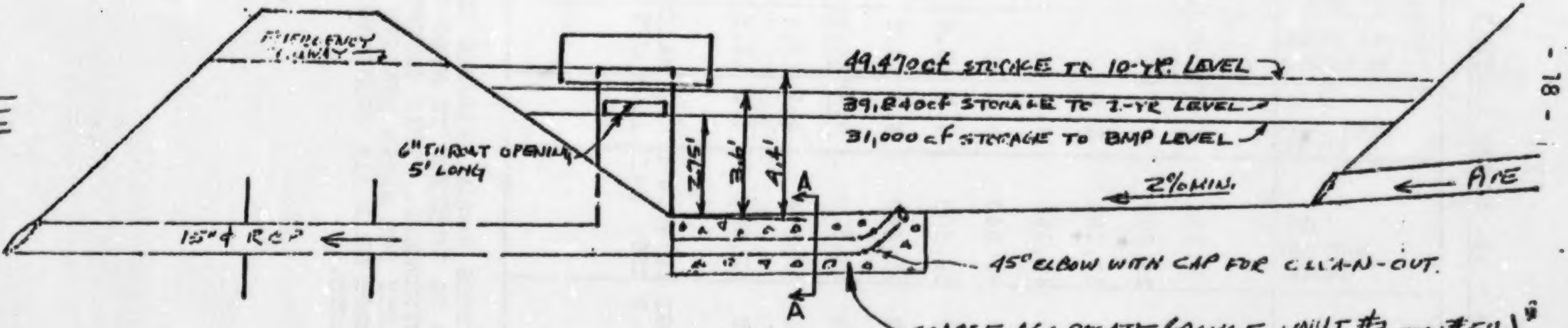
* THEREFORE MAXIMUM STORAGE IS 49,470 CF; MAXIMUM DEPTH IS 4.4'; AND MAXIMUM OUTFLOW IS 14.0 CFS. (< 15.3 CFS ALLOWABLE ∴ OK)

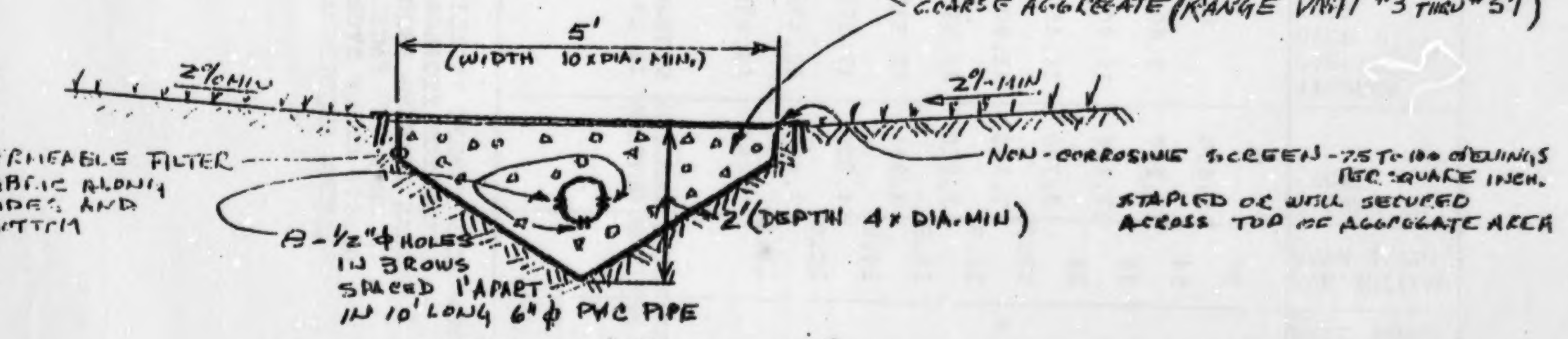
NOTE: THE PUBLIC FACILITIES MANUAL EXAMPLE SHOWS 44,490 CF OF DETENTION STORAGE IS REQUIRED TO MEET THE 2-YR and 10-YR PEAK SHAVING REQUIREMENTS. THIS DETENTION POND, MODIFIED TO BE A BMP FACILITY FOR WATER QUALITY PURPOSES, REQUIRES 49,470 CF OF STORAGE OR A 11% INCREASE OVER THE NORMAL PEAK SHAVING REQUIREMENTS.

SCHEMATIC DIAGRAM OF DETENTION POND

MODIFIED TO MEET BMP REQUIREMENTS

NO SCALE


EMERGENCY SPILLWAY
49,470 cf STORAGE TO 10-YR. LEVEL
39,840 cf STORAGE TO 2-YR LEVEL
31,000 cf STORAGE TO BMP LEVEL
6" THROAT OPENING 5' LONG
2.75'
3.6'
4.4'
A
A
15"φ RCP
2% MIN.
ARE
45° ELBOW WITH CAP FOR CLEAN-OUT.


COARSE AGGREGATE (RANGE UNIT #3 THRU #57)
5'
(WIDTH 10 x DIA. MIN.)
2% MIN
2% MIN
ERMEABLE FILTER FABRIC ALONG SIDES AND BOTTOM
8-1/2"φ HOLES IN 3 ROWS SPACED 1' APART IN 10' LONG 6"φ PVC PIPE
2' (DEPTH 4 x DIA. MIN)
NON-CORROSIVE SCREEN - 7.5 TO 100 OPENINGS PER SQUARE INCH.
STAPLED OR WELL SECURED ACROSS TOP OF AGGREGATE AREA

SEC. AA OF BMP OUTLET.

EXAMPLE #2 *

The Public Facilities Manual example of roof-top detention could be converted into a BMP in the following manner:

> Assume Glenelg soils are available nearby on-site with an infiltration rate as determined by a soils analysis, at 1 inch/10 minute. **
>
> The BMP water quality facility is designed to accommodate principally the frequent but smaller rainfall event. This would normally be included in the Fairfax County 2-year design storm.
>
> Hence the first step in this PFM example problem would be to determine the inflow-outflow characteristics of the 2-year design storm from the PFM example of a 20" diameter Denver Ring.

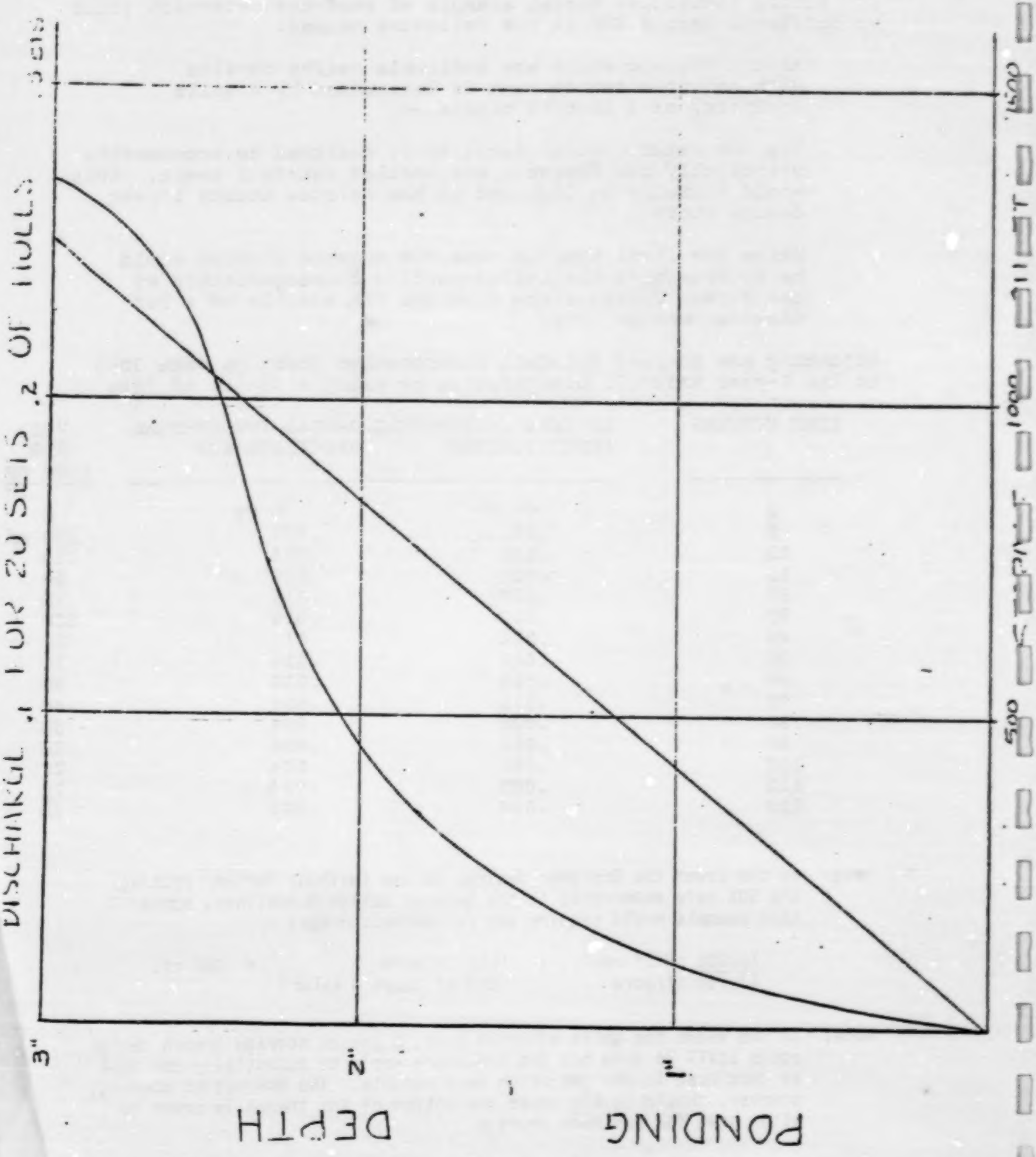
Adjusting the 10-year Rainfall Distribution Chart on page 30-6 to the 2-year Rainfall Distribution by using a factor of 75%:

TIME MINUTES	10-YEAR INCREMENTAL PRECIPITATION	2-YEAR INCREMENTAL PRECIPITATION	VOL. FOR 5000 SF
0	00 FT	0 FT.	0
5	.05	.038	190 cf
10	.032	.024	120
15	.024	.018	90
20	.020	.015	75
30	.027	.020	100
40	.022	.016	80
50	.018	.014	70
60	.014	.010	50
70	.010	.008	40
80	.008	.006	30
90	.008	.006	30
100	.006	.004	20
110	.005	.004	20
120	.004	.003	15

* Note: In the event the Designer desires to use (without further routing) the 50% rule enumerated in the General Design Guidelines, Number 8, this example would require the following storage:

$$\frac{10{,}000 \text{ sf of roof}}{43{,}560 \text{ sf/acre}} \times \underset{\text{(50\% of Chart A value)}}{1550 \text{ cf/acre}} = 356 \text{ cf.}$$

** Note: In the event the soils will not perc, a gravel storage trench design could still be done but the procedure would be essentially the same as that used in the detention pond example. The BMP outlet opening, however, should be 6"± above the bottom of the trench in order to allow area for sediment storage.


DISCHARGE FOR 20 SETS OF HOLES
.3 cfs
.2
.1
3"
2"
1"
PONDING DEPTH
500
1000
1500

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WATER DEPTH AT INLET INCHES	CAPACITY THRU 1 SET HOLES	CAPACITY THRU 20 SETS HOLES (PFM EXAMPLE PROBLEM) ONE RING	ACCUMULATED VOLUME 5000 SF.
0.0	0	0	0
0.5	.0003 cfs.	.006 cfs.	208 cf
1.0	.0010 cfs.	.020	417
1.5	.0022 cfs.	.044	625
2.0	.0044 cfs.	.088	833
2.5	.0111 cfs.	.222	1042
3.0	.0134 cfs.	.268	1250

ROUTING TABLE FOR ONE ROOFTOP RING (i.e. 5000 SF OF ROOF)

TIME MIN.	INFLOW CF	STOR. CARRY-OVER CF	TOTAL STOR-AGE	ASSUM-ED DEPTH INCHES	OUT-FLOW CFS	OUT-FLOW AVER. CFS.	OUT-FLOW CF	VOL. IN STOR. CF	CORRES-PONDING DEPTH	DECI-SION
0	0	0			0					
5	190	0	190 cfs	.40"	.004	.002	.6	189.4	.45	OK
10	120	189.4	309.4	.70	.010	.007	2.1	307.3	.72	OK
15	90	307.3	397.3	.94	.016	.013	3.9	393.4	.94	OK
20	75	393.4	468.4	1.12	.024	.020	6.0	462.4	1.12	OK
30	100	462.4	562.4	1.30	.032	.028	16.8	545.6	1.31	OK
40	80	545.6	625.6	1.46	.040	.036	21.6	604.0	1.46	OK
50	70	604.0	674.0	1.60	.050	.045	27.0	647.0	1.55	OK
[illegible]	50	647.0	697.0	1.65	.056	.053	31.8	665.2	1.60	OK
70	40	665.2	705.2	1.65	.056	.056	33.0	672.2	1.60	OK
[illegible]	30	672.2	702.2	1.60	.050	.053	31.8	670.4	1.59	OK
[illegible]	30	670.4	700.4	1.55	.046	.048	28.8	671.6	1.60	OK
[illegible]	20	671.6	691.6	1.60	.050	.048	28.8	662.8	1.58	OK
[illegible]	20	662.8	682.8	1.55	.046	.048	28.8	654.0	1.55	OK
[illegible]	15	654.0	669.0	1.55	.046	.046	27.6	641.4	1.53	OK
[illegible]	0	641.4	641.4	1.50	.044	.045	27.0	614.4	1.48	OK
[illegible]	0	614.4	614.4	1.45	.040	.042	25.2	589.2	1.41	OK
[illegible]	0	589.2	589.2	1.40	.038	.039	23.4	565.8	1.35	OK
[illegible]	0	565.8	565.8	1.35	.036	.037	22.2	543.6	1.30	OK
[illegible]	0	543.6	543.6	1.25	.030	.033	19.8	523.8	1.25	OK
[illegible]	0	523.8	523.8	1.20	.028	.029	17.4	505.4	1.21	OK
[illegible]	0	506.4	506.4	1.15	.024	.026	15.6	490.8	1.18	OK
[illegible]	0	490.8	490.8	1.15	.024	.024	14.4	476.4	1.15	OK

Assume this site has 2 - 4' wide median strips running perpendicular to the building, 100 feet long into which these two roof drains can discharge: (that is, one drain can drain into each strip and they are to be back-filled with #57 stone with 40% voids.)

The outflow from the roofdrains becomes the inflow to the percolation trenches:

TIME	VOL. IN CF	+ CARRY OVER STORAGE	TOTAL STORAGE	(POTENTIAL)* VOL. OUT CF.	STORAGE REMAINING	
0	0				0 CF	
5	.6			8.3	0	
10	2.1			8.3	0	
15	3.9			8.3	0	
20	6.0			8.3	0	
30	16.8			16 7	.1	
40	21.6	.1	21.7	16.7	5.0	
50	27.0	5.0	32.0	16.7	15.3	
60	31.8	15.3	47.1	16.7	31.6	
70	33.0	31.6	64.6	16.7	47.9	
80	31.8	47.9	79.7	16.7	63.0	
90	28.8	63.0	91.8	16.7	75.1	
100	28.8	75.1	103.9	16.7	97.2	
110	28.8	97.2	126.0	16.7	109.3	
120	27.6	109.3	136.9	16.7	120.2	
130	27.0	120.2	147.2	16.7	131.5	
140	25.2	131.5	156.7	16.7	140.0	
150	23.4	140.0	163.4	16.7	146.7	
160	22.2	146.7	168.9	16.7	152.2	
170	19.8	152.2	172.0	16.7	155.3	
180	17.4	155.3	172.7	16.7	156.0	PEAK *
190	15.6	156.0	171.6	16.7	154.9	
200	14.4	154.9	169.3	16.7	152.6	

* VOL. OUT + 1"/10 mins. x 1 ft./12 inches x 200 sf/one roof drain

= 16.7 cf/ 10 min.period

or 8.3/ 5 min. period

** TO PROVIDE FOR THIS PEAK STORAGE VOLUME OF 156.0 CF, WILL REQUIRE A

$$\text{TRENCH VOL. } \frac{40\%}{100\%} = \frac{156.0}{X} \quad \therefore \quad X = 390 \text{ CF IF AREA} = 2' \times 100 = 200 \text{ SF}$$

DEPTH = 1.95' SAY 2'

Therefore an additional 156 CF per trench or 312 CF for both trenches will be required to modify this roof-top detention facility into providing BMP purposes.

This would be:

$$\frac{312 \text{ CF}}{2500 \text{ CF}} \times 100 = 12.5\% \text{ increase}$$

of storage over that originally supplied.

NOTE: This would serve as BMP for the building only.

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Enclosure 1

ADOPTION OF AMENDMENT TO PUBLIC FACILITIES MANUAL OF THE COUNTY OF FAIRFAX, VIRGINIA

At a regular meeting of the Board of Supervisors of Fairfax County, Virginia, held in the Board Room of the Massey Building, at Fairfax, Virginia, on Monday, July 14, 1980, the Board, after having first given notice of its intention so to do, adopted an amendment to Section 1-29 of the Public Facilities Manual of the County of Fairfax, Virginia, said amendment so adopted being in the words and figures following, to-wit:

BE IT ORDAINED BY THE BOARD OF SUPERVISORS OF FAIRFAX COUNTY:

1-20A. Storm Water Runoff Quality Control Criteria

* The term "Best Management Practices" refers to a practice, or combination of practices, that is determined by a state or designated area-wide planning agency to be the most effective practicable means of preventing or reducing the amount of pollution generated by non-point sources to a level compatible with water quality goals.

Both the Water Resources Planning Board (WRPB) and the Virginia State Water Control Board (SWCB) have developed "Best Management Practices" (BMP) manuals as aids toward implementation of an economically feasible program calculated to fulfill reasonably the goals of the Federal Water Pollution Control Act (PL 92-500).

Since Fairfax County already has a general storm water management requirement for new development, it is proposed that Best Management Practices be incorporated into this existing program in the following manner:

Where volume controls and/or storage measures are used, a minimum storage volume (as determined from Chart "A") of long-term detention is to be provided for each acre of development related to % imperviousness or Rational Formula "C" factor. This will normally require modification of the outlet works or the addition of underdrains to reduce the release rates of detained storm water, and hence convert these facilities from a single purpose use to multiple purpose use. (See examples in the body of this manual for specifics). Please note that volume controls such as percolation trenches already meet requirements, without further modifications. Roof top and parking lot detention will also meet BMP requirements without modification providing the discharge can be made to pass slowly over a pervious area prior to entering a storm sewer or stream. Other measures of control may be substituted for structural measures with the permission of the Director.

Developers and their design engineers are encouraged to seek new and better methods beyond those specifically covered in the referenced WRPB and SWCB BMP manuals to achieve the goals of this storm water runoff quality control program, particularly with the end of reducing initial construction costs and ensuing operating and maintenance costs.

"Developers, in coordination with D.E.M., are strongly encouraged to seek cooperation with other planned developments in their watershed area in order to design and construct combined facilities which could serve several developing sites."

"Best Management Practices" shall be applied to all pending preliminary plats in the residential area and all commercial and industrial site plans not yet approved in the Occoquan Watershed.

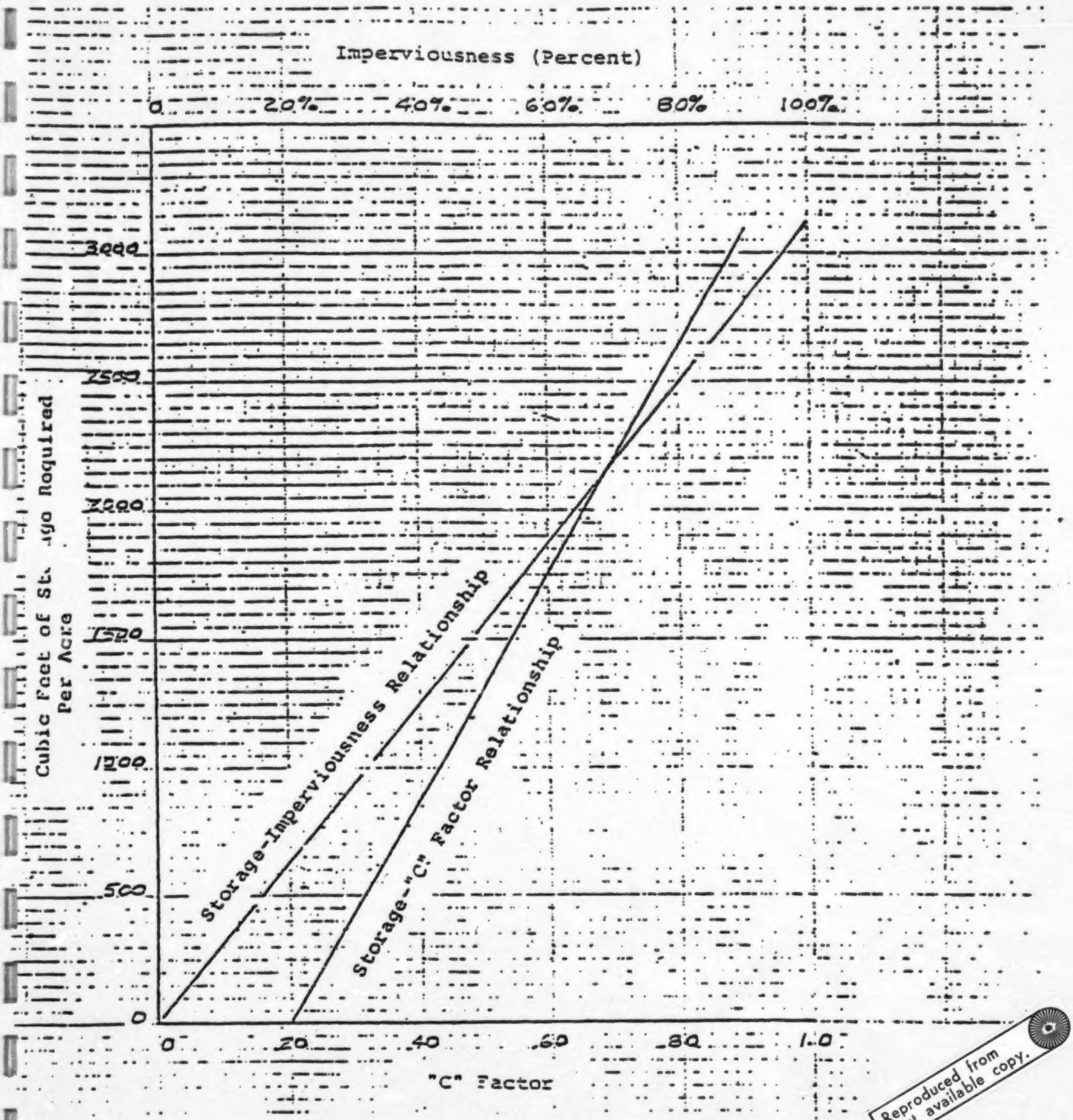
GIVEN under my hand this 14th day of July, 1980.

Ethel Wilcox Register

Ethel Wilcox Register
Clerk to the Board

CHART A

CHART SHOWING WATER QUALITY STORAGE REQUIREMENTS RELATED TO PERCENT IMPERVIOUS AND RATIONAL FORMULA "C" FACTOR*



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* Basic data derived from a report entitled "Guidebook for Screening Urban Nonpoint Pollution Strategies" Northern Virginia Planning District Commission, November, 1979.

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